THE ENGINEER

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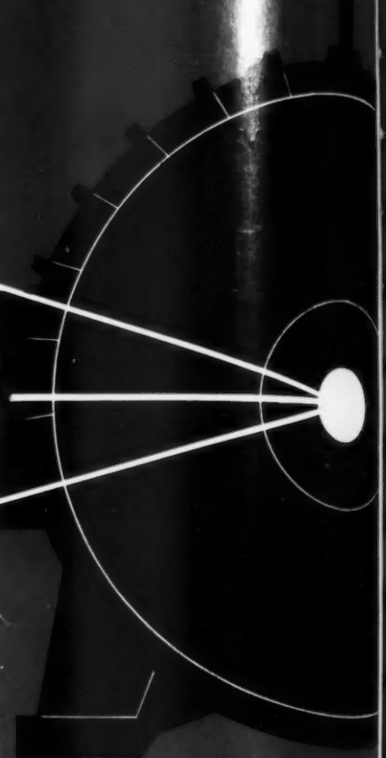

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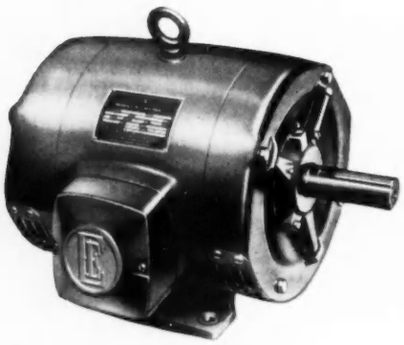

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THE ENGINEER

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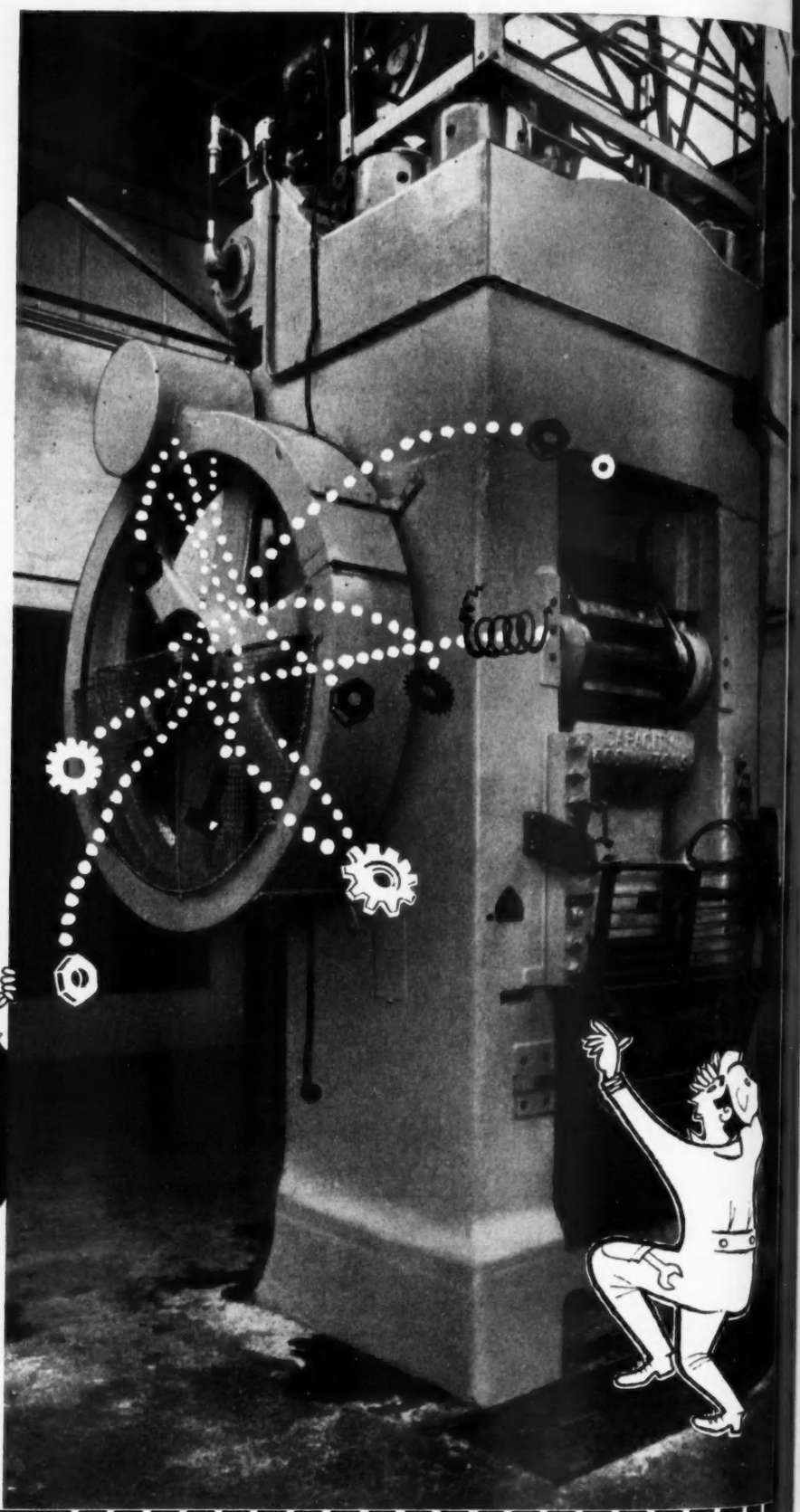

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THE ENGINEER

No. 5514 SEPTEMBER 29, 1961 Vol. 212

ELECTRICITY SUPPLY DEVELOPMENTS

As recorded on page 506 of this issue the annual reports covering the activities of the Electricity Council and of the Central Electricity Generating Board, for the year ended March 31, 1961, were presented to the Minister of Power this week. It will be noted from our review of these reports that the sales of electricity in England and Wales (96,053 million units) were 12·1 per cent higher than in the previous year and that this rate of increase has not been surpassed in the past decade. While all classes of consumers contributed to this increase, by far the largest part of it was attributable to the domestic load which, in fact, grew by no less than 17·6 per cent in terms of units used. Indeed, it was the widespread demand for space heating, particularly in the unseasonable autumn weather, which was partly responsible for the fact that the C.E.G.B. had a trading deficit of £1,500,000 in the year's operations. For, to meet the increased load, the Board was obliged to operate its older, less efficient stations, incurring high running costs, to a greater extent than had been planned. However, the major factors that helped to turn an estimated surplus of £7,500,000 into a deficit of £1,500,000 were, first, changes in the structure of the bulk supply tariff and, secondly, delays in the commissioning of new stations and transmission lines. In this connection it should be appreciated that the cost of unforeseen "outage", due to teething troubles, on a modern set, can be as high as £4,000 a day.

Another aspect of the growing demand for electricity is the heavy financial burden imposed by the capital costs of the plant and equipment programmes needed to meet the estimated future loads. This side of the picture is clearly portrayed in the Electricity Council's annual report (abstracted on page 506 of this issue). We need not dwell on this matter except to comment that the very size of these capital commitments (now approaching £300 million annually and rising rapidly) is itself a strong inducement to the Boards to exercise economy by aiming to install plant of the maximum efficiency at the minimum cost. That this fact is fully appreciated is borne out, for example, by the Generating Board's plans to install very large generating units and thereby reduce the capital cost per kilowatt. Clearly, also, there is a sharp incentive to seek refinements in the method of forecasting future demands. Here, the prospects, when one is "crystal gazing" five or more years ahead, are problematical. Possibly the increased use of computers may help by enabling the effects of unforeseen economic changes to be assessed more quickly so that the necessary modifications to a programme can be made with the minimum upheaval.

Such an idea may seem far-fetched but it is instructive to recall that the Generating Board is making extensive use of computing techniques in system operations. One interesting project is a long-term study which is in hand to assess to what extent automatic control can be applied to power stations and Grid Control. In this investigation information is being collated about system operation, with a view to expressing the data in terms that can be handled numerically by automatic machines, to ensure that any automatic control that may be introduced will be consistent with manual control. This study will include the response of the whole interconnected system to any disturbances. One aim of the work is to yield additional information analysed and presented to operators in such a way as to make manual control easier or more precise. Of more immediate interest, perhaps, is a device, soon to be installed, which is designed to assess, automatically and continuously, what would be the effect, on a sector of the supply system, of isolating any particular line. It will show the operator where there is a risk of any lines becoming overloaded if any one line in the system should become unserviceable. It would be hard to overemphasise the value of operational aids such as these on a large interconnected system, which is growing so rapidly that it is expected to face a maximum demand of over 33,000MW in the winter of 1964-65.

WATER RESEARCH ASSOCIATION

Last week the Press was invited to inspect the new Laboratories of the Water Research Association at Medmenham near Marlow in Bucks. The Water Research Association is one of the younger and comparatively less-known of the industrial research organisations; it was set up in 1953, and the present director, Dr. R. G. Allen, began work in temporary premises at Redhill in 1955. Now, the Association is financed jointly by the industry it serves and by a D.S.I.R. grant; it moved into the new research station at Medmenham in the Spring of this year, and has thus been in a position to go ahead with a comprehensive programme of research for only a few months. The importance of its work was stressed last week by referring to the future prospects of the water supply industry in this country, a position summed up by the estimates for the gross daily demand for water in 1965 — 4,500 m.g. — and the estimated supply available — 4,653 m.g. — at that time. Demand is growing at a rate of about 2½ per cent per

year; these figures do not take into account the demand for irrigation, which might be as much as 240 m.g.d. in a dry season by 1965, the Association considers. The small margin between supply and demand will not come as a surprise and it is of course true that the dryer regions of the country — notably in Essex, according to the figures given in the recent hydrological survey of the Essex rivers and Stour — will be feeling a shortage in a very few years, even if agricultural irrigation does not develop. On the other hand, the nature of the general problem of water supply is well illustrated by another figure quoted, namely that the average price of this commodity, delivered, is 6d. a ton.

Although it is clear from these figures that the overall picture of the industry and its problems is before the eyes of the Association, it was principally researches devoted to matters of detail in the supply and purification of water which were demonstrated to the press last week. The research station at Medmenham has a plentiful supply of raw water from the Thames, and is organised in sections dealing with chemistry, physics, hydrology, biology, and "plant process". Recent examples of research have included: a test programme for plastics pipes; use of a "ferret" (a plunger-like device which travels along inside a pipe to clean it) trailing a magnetic device which enables the position of the ferret to be ascertained, and which will also enable intelligence, e.g. the position of leaks, to be transmitted to an observer; and a study of the chemistry of the coagulation process.

The researches of two of the divisions are likely to prove of special interest. The hydrology division has an ambitious programme covering assessment of land use in relation to water yield in an upland catchment, and a study of the properties and long-term yield of aquifers, and guidance on their artificial replenishment. Its main attention however, is to be devoted to the support of an integrated national programme of hydrological research including better hydrological measurements by water undertakings, and an upland study of rainfall and evaporation. The "plant process" division is also likely to prove of special interest to engineers. Here, pilot plants will be erected and tested in the largest of the laboratories at Medmenham, to study existing water treatment processes, to develop the laboratory-scale findings of the chemistry division, or to study plant problems of particular members.

THE PHILOSOPHY OF MUSEUMS

Museums are variously defined but little is said as a rule about how they work, what their aims should be, what they should preserve and how they should display what they have. It may be said that these things are a matter for those who run the museums; and so they are, but not solely, at least in public museums. For a public museum must have the interest and support of the public but also of those with specialised technical know-more true than in a technical museum. This kind of museum needs not only the support of the general public but also of those with specialised, technical knowledge in the particular field it serves. Such support will always be more freely forthcoming if people know what the museum is trying to do. There have been many changes in museums in recent years, and if it was enough in the past, for some museums, at least, that they should collect and preserve, in a dusty and uninspired way any object within their sphere and their capacity to house, it is certainly not enough to-day. Selection, preservation and display techniques have improved and to-day there are some very good technical museums. To single out a particular museum for mention would be invidious, but it is fair to say that the aims of the good ones were accurately defined by Lord Montagu in a recent address to the International Commission for Transport Museums in London.

It is true that Lord Montagu was speaking only of transport museums and in particular of motor museums, but his remarks apply equally, in many cases, to other museums as well. No one, for example, will dispute the need for a museum to be "alive"; there is no room to-day for a mausoleum effect. There are difficulties. Neither old motor-cars nor any other kind of machinery can be kept running all the time. But at least they should, if at all possible, be put into full working order and allowed now and then to run in the way they were intended to run. Then the overall museum plan can, as Lord Montagu said, aim at showing the evolution of the exhibits (whether they be cars or anything else); and showing it in a way that any intelligent layman can understand. In a technological museum it may be desirable not only to show historic exhibits but also to illustrate by suitable diagrams or models the principles of processes and mechanisms, etc. It may be desirable to discard the freak that came to nothing or at least not to place it on display and to keep instead an exhibit which represents something once common — often too common to have been kept at all, unfortunately. A museum cannot keep everything in its particular line and it must be selective. What it does keep, moreover, should be as fully documented as possible. In fact documentation of the entire sphere in which the museum operates is vital, whether it has exhibits to illustrate its records in all cases or not. This does not mean, however, that all the knowledge implied by the word "documentation" should be displayed. Esotericism in a museum is not for outward show; but to the specialist interested enough to make inquiry the full detail should be available somewhere in the recesses of the museum.

Documentation, like exhibits, must be kept up-to-date, for as Lord Montagu so rightly said, history does not stop at a particular date; it is being made all the time. Neglect of this obvious fact in the past is the cause of many museum difficulties at present, and the past does not have to be very distant. It is difficult even now, for example, to find out much about some perfectly ordinary cars made as late as 1939. A tremendous amount of very valuable information and many vital exhibits have been lost to us because of neglect in the past. One cannot repair the omissions of one's forebears, but one can avoid making the same mistakes. That is well enough known to those who run museums, but it needs to be driven home to people who may be able to help with information, documents or specimens, but have never thought of trying to do so.

ROYAL NAVY'S TECHNICAL OFFICERS

During recent months, the Admiralty has announced two important changes affecting officers of the Technical Branch of the Royal Navy and it will be of much interest in the coming years to analyse and evaluate the results of these changes on the Navy's efficiency. The first change is the introduction of a direct graduate entry into the engineering specialisation, arising from the growing need for qualified technical officers. The second, which came into force on July 1, is the amalgamation of the engineering and electrical specialisations into a single engineering specialisation. Until recently the only

avenue, direct from civilian life, to a General List commission — which offers the opportunity of promotion to the highest ranks — has been via the Dartmouth cadet entry between the ages of seventeen and nineteen. Under the new scheme university graduates with suitable engineering degrees or degree equivalents, up to the age of twenty-five years, may be awarded General List commissions in naval engineering. Entries will be made once a year in September, successful candidates joining as acting sub-lieutenants with promotion to acting lieutenant eighteen months after joining the Royal Navy and confirmation in the rank following on the satisfactory completion of training. After a year of short introductory courses and sea training, officers go on to various naval specialist schools for professional application courses lasting a further twelve to eighteen months.

The nature and length of these professional application courses will depend to some extent on the kind of degree acquired. Under the amalgamation, engineer officers, both mechanical and electrical, will serve in one of four groups with the Fleet — Marine Engineering; Weapons and Radio Engineering; Submarine Engineering; and Air Engineering. This fusion of the Navy's technical officers, with its emphasis on functional rather than — as in the past — professional lines of employment, is designed to produce engineers of wide knowledge and experience, able to fill appointments which are not limited to a single engineering science. Though the desirability or otherwise of amalgamation has been the subject of much discussion in the Fleet, the Admiralty's decision results directly from the recommendations of Vice-Admiral Sir Stephen Carhill's Committee set up in 1958 to examine the existing divisions of responsibility between the engineering and electrical specialisation. In the words of the Admiralty announcement to the Fleet: "An assessment of the Navy's future needs, the rapid expansion in electronic techniques and the trend towards automation and nuclear propulsion, all point to the ever-increasing complexity of naval equipment. Officers are needed who will not only be competent to introduce and handle this equipment but will also be as versatile as possible in both mechanical and electrical engineering."

A great deal of modern equipment in the Navy combines electrical and mechanical techniques and in the Admiralty view requires to be treated as an entity under the control of one engineer officer. Officers in future will be trained to mechanical or electrical chartered engineer standard and receive post-graduate instruction necessary to fit them for employment in the Fleet. Their academic qualifications will normally be an engineering degree and the young officer, on completing his academic course, will undergo an application course to fit him for one of the three main components of the Service — surface ships, submarines or the Fleet Air Arm, normally remaining in one of them throughout most of his service as Lieutenant and Lieut.-Commander. The effect of this change is to divide the engineering task in a ship into two departments: (1) Marine Engineering and (2) Weapons and Radio. Thus, to the existing engineering responsibilities are added power generation and distribution and all the common services of the ship for which the new Marine Engineering Branch will be responsible. The Weapons and Radio Branch will cover the remaining existing electrical responsibilities together with those of the Ordnance Engineer Officer, each of the two departments having a Head responsible to the Captain. Hence, one officer, called the Weapons and Radio Engineer Officer will be responsible for the custody, efficiency, availability and maintenance of the complete weapons system, instead of two or even three officers as hitherto.

The engineer officer of the future will have as his background training his mechanical or his electrical engineering degree. To this will be added his application training and his functional experience in the Fleet. There will, of course, be critics of the change to the functional approach on the ground that it may produce jacks-of-all-trades. But the answer must be that in modern equipment in a warship, mechanical and electrical engineering are so mixed up that they cannot continue to work in watertight compartments. But what about the more senior ranks — Commander and Captain? The majority of posts in these ranks require less detailed knowledge and more ability as a technical administrator. A proportion of these posts will be suitable for any senior engineer officer, though the Admiralty points out that indoctrination may sometimes be necessary. The need to provide experts in comparatively narrow fields is recognised by the fact that some junior officers will be given specialised training and employed on such work during their early service. Some of them will return for further appointments both as Commanders and Captains. The existence of, and the need for, the expert technologist as well as the technical administrator appears to be fully accepted and the chances of promotion on the General List for the former will not be jeopardised because of his special employment.

The Engineer—100 Years Ago (SEPTEMBER 27, 1861)

"Mont Cenis Tunnel"

"M. Noblemaire, a French engineer . . . has made a lengthy report describing M. Sommelier's apparatus . . . [then being erected for driving the Mont Cenis tunnel]. The machinery . . . acts by the compression of air to a pressure of five atmospheres, that is to say, an available pressure of rather under 60 lb per square inch." At the Bardonnèche (Piedmontese) end of the tunnel water was brought by a canal two miles long and used to compress the air by alternately arresting and releasing the water head in a pipe, so driving entrapped air through a non-return valve into a receiver. At the Modane (French) end, water wheels driving pistons in cylinders partly filled with water and having self-acting inlet and delivery valves were used; this apparatus more nearly approximated to a reciprocating compressor of modern design.

Of the drills or "percusseurs" . . . "no less than eight distinct machines . . . are employed . . ." on each working face of the tunnel. The drill or "chisel" was fixed in a socket on the end of a spindle passing through a cylinder 2¾in bore, and part of the spindle was enlarged to form a piston. A separate compressed air engine controlled the air admission to the cylinder and rotated the drill stepwise. The drill struck 200 times a minute and had a stroke of 6 in. "In the rock in which they have been working each drill makes from eight to eleven holes in six hours, each hole generally 3ft in depth and rather more than 1¼in diameter. A water pipe supplies water constantly, and under a pressure of 60 lb per square inch, to the drill."

Electricity Supply in England and Wales

The third annual reports of the Electricity Council and of the Central Electricity Generating Board, for the year ended March 31, 1961, were published this week. The following article, consisting mainly of abstracts from these reports, reviews the electricity supply industry, beginning with the trading results and financial prospects and proceeding to technical developments in generation and transmission. A section on research progress is included.

SALES of electricity reached 96,053 million units, and were 12·1 per cent higher than in the previous year. This rate of increase has not been paralleled for ten years. All classes of consumers—domestic predominating—contributed to the increase. The Area Boards in the South met the highest overall increases, but sales also rose steadily even in the coal producing areas, where there is a growing tendency to replace domestic coal with electricity. Sales to domestic consumers rose by 17·6 per cent during the year to a total of 31,636 million. There was a widespread demand for space heating. About 97 per cent of all households are now connected to the supply and the average consumption per consumer in 1960-61 was 2271 units. The greater part of the increase in domestic sales came from the more extended use of existing appliances rather than from the addition of new ones.

In the industrial sector the increase in sales of electricity over 1959-60 was 8·2 per cent. Iron and steel, and chemicals recorded the greatest increases in consumption.

In farming, the end of the year showed 83·8 per cent of the potential total of farms in England and Wales connected to the supply mains. Since that time the target figure of 85 per cent to be connected by 1963 has in fact been achieved—eighteen months ahead of schedule. However, the rate of connection is now declining as development extends into the more remote and sparsely populated areas and becomes more and more costly.

Sales to commercial consumers increased by 14·4 per cent, attributable mainly to the extended use of electricity for water and space heating during the unpleasant autumn weather. Electricity also continued to make an important contribution to road safety through the further development of street lighting systems, and interest continued to grow in the storage heating of roads to prevent icing.

The consolidated surplus on the year's trading operations was just over £16,000,000, after providing for depreciation and meeting all interest charges ; this compared with the previous year's surplus of nearly £27,000,000. The lower overall surplus was due mainly to the pay awards and increased fuel prices, mentioned above, and to the reduction of £3,000,000 in the surplus on contracting and sales of fittings.

The surplus, as in previous years, was wholly employed in financing the capital requirements of the industry. The internal resources employed during the year in meeting capital requirements amounted to 46·2 per cent of the total investment expenditure.

Future Capital Investment and Financial Policy

The first chapter of the Electricity Council's Report deals with the financial consequences of the upward surge in electricity sales and the need for an increasing level of new construction to meet future higher demands. A heavy programme of electricity expansion will be required to keep pace with the demand, and this calls for capital investment on a very large scale.

The Electricity Council will shortly be seeking authority for the industry to proceed to the next stage of borrowing under the Electricity (Borrowing Powers) Act, 1959. When the seven-year programme of capital development up to March 1965 (on which the borrowing powers under this Act were based), was prepared in 1958 the industry envisaged that depreciation provisions, surpluses and other internal resources would provide about 48 per cent of the total capital required over the whole period. This proportion seemed to strike a reasonable balance between the interests of consumers and the need to limit borrowing. But it is now expected that the industry will have to face a maximum demand of over 33,000MW in the winter of 1964-65 (more than 12 per cent above the forecast made in 1958) and the most recent estimates suggest that subsequently, in the two years to 1966-67, it will rise by a further 5000MW. To meet this the capital estimates made in 1958 will have to be increased by some £200 million to cover the period to the end of 1964-65, and the continued rise in demand would call for an outlay in excess of £400 million a year on fixed assets in the succeeding two years.

To reach the degree of self-financing involved requires the earning of increasing surpluses year by year, these surpluses together with depreciation provisions being the main source of finance from internal resources. It was for this reason, together with the necessity to cover increased costs of over £20,000,000 per annum from wage and salary increases and a rise in coal prices, that the Boards were obliged to announce increases in most of their tariffs last year. Even so, these new tariffs did not take account of a further increase in costs of approximately £100,000,000 a year arising from changes in the tax on fuel oil in the Finance Act, 1961.

The self-financing programme depends upon achieving planned surpluses. The additional capital requirement of £200 million above the forecasts to 1964-65 and the heavy programme foreseen for subsequent years have called for a full financial review, which is taking place now in the setting of the Government's White Paper on the Financial and Economic Obligations of the Nationalised Industries. As a result financial objectives for the Boards will be determined for a period of five years, subject to review annually, within a framework settled with the Minister of Power. For the industry as a whole this will called for increased annual surpluses during the period. These higher surpluses will be essential if the industry is to achieve a financial performance in accordance with the requirements of the Government's White Paper and is to find the capital resources it needs, while keeping its borrowings within manageable limits.

C.E.G.B. Trading Results

During its third year of operation, the Central Electricity Generating Board had a deficit of £1·5 million, compared with surpluses of £5·4 million for the previous year and £10·8 million for 1958-59. The deficit was, paradoxically, partly due to unexpectedly heavy sales of electricity during the year, particularly during August, September and October of 1960, when sales averaged 17·4 per cent more than in the same months of the previous year. In consequence, the Board was obliged to operate older, less efficient stations, many in high coal-cost areas, to a greater extent than planned. Costs were increased because more fuel was used in the older stations than would have been required to produce the same amount of electricity in newer, more efficient stations.

Trading income was £425·2 million, 11·4 per cent more than in 1959-60, while expenditure at £426·7 million was 13·4 per cent higher. Expenditure on fixed assets, at £196·2 million, was 8·6 per cent less than in 1959-60, and, of this, £106 million was spent on power stations, including £53,000,000 on nuclear stations, and £31,000,000 on the national Grid.

The Generating Board's endeavours to hold down electricity prices must also be taken into account. In 1960-61 the Board retained the same tariff as for the previous year and were consciously working to a narrow margin.

During the year under review, the Board reluctantly increased the tariff by approximately 2½ per cent overall for the present financial year 1961-62. In raising the tariff, the Board took into account increased costs, including wage and salary awards and higher interest rates, and their policy of providing an increasing proportion of capital needs from internal resources.

Power Stations

At the end of March, 1961, the Central Electricity Generating Board owned 230 power stations, with a total maximum output capacity of 27,067MW, 1668MW (sent out) of new plant having been installed during the year.

Total generating capacity has more than doubled in the past ten years but, as a result of the policy of installing larger sets, it has been possible to reduce the number of power stations by just over 20 per cent.

Four new steam stations were brought into operation, at Staythorpe " B," near Newark, Notts. ; Skelton Grange " B," near Leeds ; Rugeley, Staffs. ; and Uskmouth " B," near Newport, Mon.

During the year, the first reactors of the Board's two nuclear power stations at Berkeley, Glos., and Bradwell, Essex, were substantially completed. Pre-commissioning tests were commenced in preparation for fuel loading (which began last month). At the Hinkley Point nuclear station in Somerset, the No. 1 reactor pressure vessel was completed and tested [see page 508].

Good progress continued with the construction of the nuclear station at Trawsfynydd, Merionethshire, and contracts were placed for a 550MW nuclear station at Dungeness, Kent, and for a 580MW nuclear station at Sizewell, Suffolk. The Minister of of Power gave consent for the building of the Board's seventh nuclear power station, of 600MW capacity, at Oldbury, Glos.

At March 31, 1961, the Grid system consisted of 7532 miles of overhead lines and underground cables, of which 1488 operated at 275kV, 5734 at 132kV and the remainder at 66kV or less. About 474 miles of main transmission line were completed during the year.

It was decided to adopt 400kV for new main transmission lines due to be commissioned in

and after 1965 and gradually to convert many existing 275kV lines to 400kV working.

Work continued on the cross-Channel power link which will connect the 275,000V Supergrid to the 225,000V French network (cable laying for this £4·6 million project was completed in June, for commissioning this year).

Generation and Fuel Supplies

Over 111,400 million units of electricity were generated in the power stations in England and Wales during 1960-61, 10·8 per cent more than in the previous year ; this was the highest rate of increase recorded since 1954-55.

The total amount of fuel consumed for all purposes amounted to 54·3 million tons, consisting of 48·9 million tons of coal and coke and 5·4 million tons of oil—a total of 58·1 million tons expressed in terms of " coal equivalent." Average thermal efficiency of all 230 stations rose to 26·80 per cent, compared with 26·53 per cent in the previous year, and 21·69 per cent ten years ago. The calorific value of the coal supplied to the Board during the year continued to fall. The average calorific value fell from 10,383 B.Th.U. per pound in 1959-60 to 10,206 B.Th.U. per pound in 1960-61 (good quality domestic coal has an average calorific value of about 14,900 B.Th.U. per pound).

Peak Demand.—The maximum demand for electricity in 1960-61 occurred on Tuesday, December 13, 1960, and amounted to 24,445MW, which was 1356MW higher than the maximum demand the previous year. At the time of maximum demand the plant actually available for service totalled 24,192MW sent out, which represented an availability of 91·8 per cent.

Television viewing is having a noticeable effect on the daily pattern of demand, more particularly because the pattern of variation in demand for electricity during the evening is strongly influenced by the routine of domestic consumers. Normally it can be expected that the switching on and off of cookers, electric irons, electric kettles, &c., although following a broadly common pattern, will not occur simultaneously in a great many households. The effect of television tends to be to synchronise routines in a large number of households ; at the end of a popular programme, domestic appliances tend to be switched on almost simultaneously, and the demand may be increased by as much as 600MW in one or two minutes. The demand created by television sets is of the order of 500MW, and it appears that although a certain number of people stop viewing, the television sets are not switched off. The rise in demand at the end of a programme appears to be related to the popularity of the programme, and in order to make arrangements for stations to be ready to meet the sudden increase, the Board's control engineers assess in advance how closely the programme will hold the attention of viewers, taking into account past experience and operational records.

System Load Factor.—The system load factor for the year, based on the maximum demand supplied, was 49·4 per cent. This compared with 46·9 per cent for 1959–60. Because of the effects of varying weather conditions, actual yearly figures, calculated from the metered maximum demand and metered units supplied, may not give a reliable indication of the trend of utilisation of equipment. An assessment has therefore been made of the load factors which would have applied if the weather at the time of the winter maximum demand had been of " average-cold-spell-severity," and if the output of electricity had corresponded to normal weather throughout the year. The adjusted load factors for 1950–51, 1959–60 and 1960–61 are given below :

Year	System load factor (adjusted for weather conditions)
1950–51	43·2 per cent
1959–60	47·4 per cent
1960–61	48·5 per cent

The trend towards higher system load factors, which has been evident for several years, was maintained in 1960–61.

Design and Development of Generating Plant

The development of larger high-performance generating units continues, which should lead to further savings, both in capital cost of power stations and plant and in operating costs. During the year, orders were placed for four units of 350MW (installed capacity) and eight of 500MW. All have single-shaft turbo-generators, and are being designed for steam conditions of 2300 lb per square inch and 1050 deg./1050 deg. Fah. reheat. These machines are characterised by multiple-flow low-pressure cylinders, for which new methods of support, designed to ensure freedom from vibration and foundation settlement, are being developed and applied.

Two supercritical units of 375MW each, with steam conditions of 3500 lb per square inch, 1100 deg. Fah., reheating to 1050 deg. Fah., were ordered during the year.

The prototype water-cooled stator windings at Bold " A " and Tilbury gave satisfactory service, and all the generators ordered in the last year will have stator cooling of this type with the rotors directly cooled by hydrogen, except for the Dungeness machines, where the rating of the generators does not justify the use of direct water-cooling.

Rectifier excitation has been developed satisfactorily, and all large generators will in future have a.c. exciters directly driven from the main shafts, used in conjunction with air-cooled static silicon rectifiers and voltage regulators incorporating magnetic amplifiers.

A 15MW Bristol-Siddeley " Olympus " gas turbine was ordered as an experimental peak-load plant. This unit incorporates the " Olympus " aircraft jet engine driving a generator, and is being installed as a joint venture by the Board and Bristol Siddeley Engines, Ltd., to assess the merits of this form of generation for peak-load operation.

All units of 300MW and above have turbine-driven boiler feed pumps which are integrated into the feed water heating system. This type of drive is not tied to the electrical supply frequency and therefore has the advantage of choice of optimum speeds. The design of suitable machines and systems proceeded satisfactorily. In some of the earlier plants, the boiler feed pumps were placed after the feed water heaters—which were subjected to an operating pressure of about one-third of the boiler pressure. The development of economical high-pressure feed-water heaters capable of operating at full boiler pressure has resulted in the placing of the feed pump before the heaters in the designs for the 350MW and 500MW plants ordered during the year.

Because the purity of feed water to boilers generating steam at high pressures must be maintained at a very high standard, condensing plant designs incorporating an interspace between the cooling water and the steam were developed, so that if a tube fixing leaks, the condensate is not contaminated.

Investigations into the possibilities of the low level, or stack, economiser showed that at the decreasing load factors of conventional plant, the economics are not so favourable for conditions in England and Wales as had been anticipated from American reports. The use of air instead of steam for soot blowing in boilers received consideration, and experiments on this system have been arranged at Leicester.

A contract was placed for a digital computer and associated equipment to control automatically the start-up of one of the boilers at West Thurrock ; experience will be obtained from this installation of the value and reliability of the equipment. The first trial installation of automatic data logging equipment was commissioned at Northfleet, and a second was ordered. Experience with these two installations will indicate whether it is worth installing this equipment more widely in power stations.

An 11kV distributing system is required in the new stations so supply the large amounts of electrical power required to drive the large auxiliary motors within the station ; the voltage is stepped down to 3·3kV and to 415V for the smaller auxiliaries. Variable-speed slipring induction motors with liquid controllers will be increasingly used for driving starting and standby boiler feed pumps ; the motors for the 375MW supercritical unit at Drakelow " C," for example, are rated at 11,400 h.p., 11kV, 980/490 r.p.m. At West Thurrock, slip energy recovery equipment was ordered for use with the variable-speed slipring motors associated with the electrically-driven boiler feed pumps. The tendency for circulating water pumps to be designed for increased outputs at relatively low speeds has made synchronous motors more attractive than hitherto, and at Drakelow " C," the pump motors of this type have a rating of 3300 h.p., 11kV, 333 r.p.m.

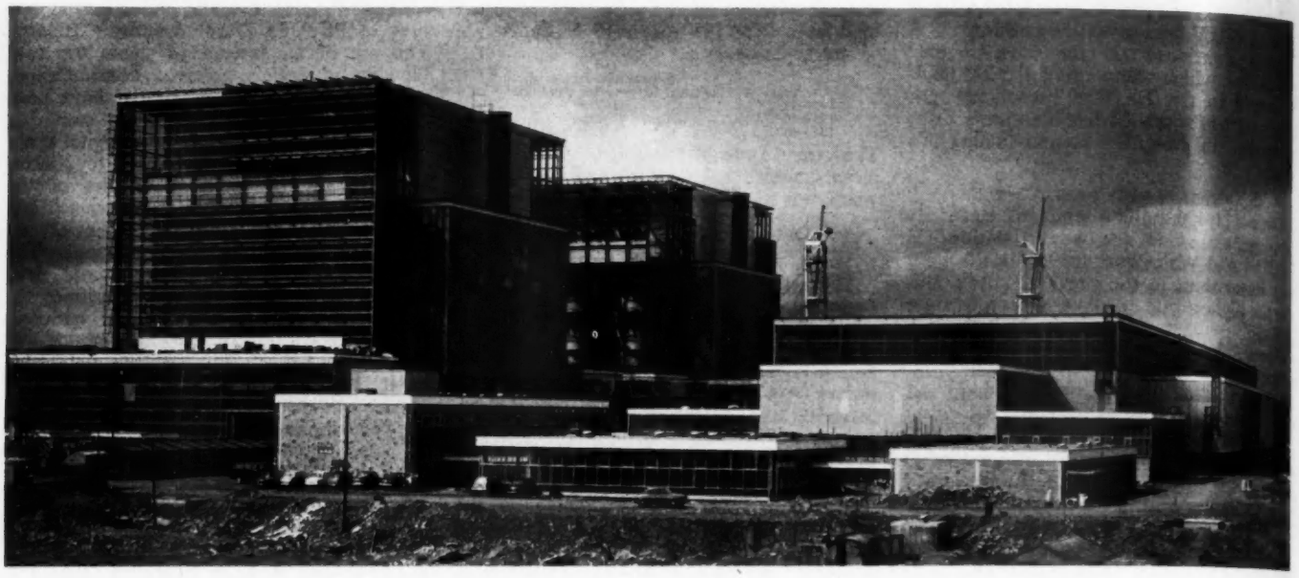
Experience with the cooling tower at Staythorpe " B " power station demonstrated that asbestos cement can compete with timber for cooling tower packings, and a number of other towers with asbestos cement packing are now under construction. The extensive tests carried out at Staythorpe enabled the theory of counter-flow natural draught cooling towers to be further developed. The Board's engineers are collaborating with the manufacturers on the design of cooling tower shells with the aim of using computer techniques to refine the calculation of the reinforcement steel required for any size and shape of tower.

Transformers rated at 400 and 425MVA will be required for the 350/375MW generating sets now on order, and design work in connection with transformers suitable for the 500MW sets rated at 570MVA, stepping up directly to 400kV, shows that the transport weight of a single three-phase transformer will not greatly exceed the maximum transport weight on which generator designs have been based. It was thought at first that two transformers, each rated at 285MVA, would be required, but developments during the year suggested that one three-phase, 570MVA transformer may be practicable, subject to detailed transport investigations.

Design and Development of Nuclear Plant

Considerable effort was devoted to designing gas-cooled reactor cores which accommodate the changes in physical properties which occur during the irradiation of graphite. Where necessary, modifications were made to the cores of reactors under construction.

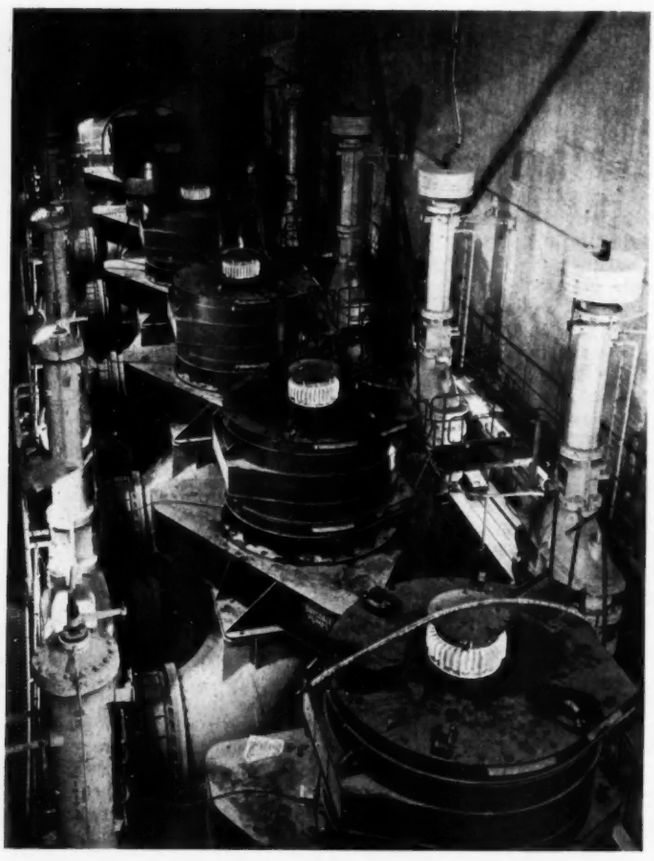
Work on fuel elements by the United Kingdom Atomic Energy Authority and the consortia of manufacturing firms engaged on the nuclear stations resulted in modifications to the design of elements to give adequate life in the reactors and the necessary design



Progress at Hinkley Point

The photographs reproduced here indicate progress on the 500MW nuclear power station which is being built at Hinkley Point, Somerset, for the Central Electricity Generating Board, by the English Electric, Babcock and Wilcox, Taylor Woodrow Atomic Power Group. Civil engineering work is nearing completion. On No. 1 reactor concrete is now being poured to form the 5000-ton, 11ft thick pile cap structure (100ft above ground level) which will form the main fuel charging and discharging floor above the pressure vessel. Laying of the graphite core of No. 1 reactor is now starting and it is expected that fuel loading will be started in February, 1963. No. 2 reactor is programmed to be about six months behind No. 1.

The first reactor building, on the left of the illustration ABOVE, is almost complete ; passenger and goods lifts are in service and plant is being installed for fuel loading and reactor instrumentation. Burst-slug-detection equipment is being installed and the associated precipitator panels and tubing are in place as are the motor-generator sets for the control rod motor drives. All the six main gas circulator casings are in position. The six boilers for No. 1 reactor are now fully tubed and the 6ft diameter gas ducts of tubular steel between the pressure vessel and the boilers are being fitted to be ready early next year for testing of the coolant gas circuit, including the circulators. Inside the shielding the 67ft diameter pressure vessel, fabricated on site by Babcock and Wilcox, is complete and has been stress relieved and pressure tested and is fitted with its complement of standpipes and nozzles. The support plates for the graphite core are being installed inside the pressure vessel.



The second reactor building, on the right of the UPPER PICTURE, is well advanced. The main gas circulator houses are complete. All six drive motors for the gas circulators are on site. The pressure vessel has been stress-relieved and pressure tested. Welding of standpipes to nozzles is in progress. Some of the standpipes, which will protrude above the pile cap floor, can be seen in position on the left of the illustration BELOW.

For the cooling water system there is an intake structure about 2000ft offshore, connected by tunnels to a deep pump-house (illustrated LEFT) with distribution culverts and discharge works at the east end of the site. Cooling water requirements will be 35,000,000 gallons per hour, but the intake structure is large enough to handle 85,000,000 if future developments require it. Each of the six 1750 h.p. vertical centrifugal pumps has a capacity of 96,000 gallons per minute. The 740ft-long turbine hall with its steel superstructure covered in glass and aluminium sheeting is almost complete. The first of the six English Electric main 93·5MW turbines is being installed above its condensers.

As seen in the TOP PICTURE the 400-ton " Goliath " crane is being dismantled for transportation to the site of the 580MW nuclear power station which is being built by the same group of companies at Sizewell.

changes were incorporated into the first charges of fuel at Bradwell and Berkeley. Safety reports for these stations were submitted to the Ministry of Power in accordance with the statutory licensing requirements : the reports covered the protection of persons on and off the site from the effects of nuclear radiation during normal operation and under reactor fault conditions. During the preparation of these reports, extensive studies using large analogue and digital computers were carried out on reactor transient conditions. Special attention was given to the design of the circuits and devices which protect the reactor from damage under fault conditions, and the Board is supporting the development of components employing semi-conductors in place of conventional relays and thermionic valves.

Reactor pressure vessels made of reinforced concrete instead of steel plate show promise of significant technical and economic advantages, and developments are being encouraged. Continued attention was given to advances in reactor design in order to reduce capital costs and the stations ordered during the year show technical and economic advantages over previous plants. Preliminary consideration was given to a more advanced type of reactor based on the prototype advanced gas-cooled reactor (A.G.R.) which is being constructed by the United Kingdom Atomic Energy Authority at Windscale.

Power System Analysis.—A number of power system analysis programmes were translated for use with the Board's IBM 709 computer. On the " Pace " analogue computer, further studies took place to determine the performance of modern large turbo-alternators when subjected to system disturbances. To cope with the large volume of system studies required for development plans, a large new 50 c/s network analyser was ordered. Plans were also made to commission a d.c. transmission simulator, which will be used to study problems likely to arise on the cross-Channel cable, and also general problems in d.c. transmission.

Transmission Plant Design and Development

Switchgear and Substations.—For the new 400kV grid system, substations, circuit-brakers and associated equipment for a rating of 400kV, 35,000MVA, 4000A and 2000A at normal current are being developed. Arrangements were made to issue final design and performance specifications to manufacturers in May, 1961, to ensure that development work can be completed in time to commission the first substation in 1965. Equipment of the ratings required is not yet obtainable from any manufacturer in the world. Special attention is being given to substation design to give the lowest possible outline consistent with an acceptable plan area, and special busbar and conductor arrangements are being investigated. The standard design of substation envisaged will be adaptable for enenclosure within a building in areas of severe industrial air pollution, or where they are exposed to salt sea-spray.

The designs of four 275kV, 15,000MVA, 2000A circuit breakers for the uprated 275kV system were completed, and prototypes tested ; all four designs are expected to receive final approval at the end of 1961. Designs of 275kV, 15,000MVA, 2000A isolators were completed and tested, and the design and testing of current-transformers, line traps and other ancillary equipment for these ratings is expected to be complete by the end of 1961.

All equipment in new 275kV substations is rated at 15,000MVA, 2000A, and the design work entailed in uprating existing 7500MVA substations to 15,000MVA, 2000A with the minimum of " outage " time and modifications to civil works is nearing completion. The installation of high-speed, automatic-reclosing equipment and circuit breakers at the terminal end of 275kV lines continues, and the operation of this equipment under transient fault conditions was satisfactory.

New designs of indoor metal-clad units and outdoor circuit breakers together with associated equipment for 33kV, 1000MVA, 2000A are now well established for use at Grid supply points with 90 or 100MVA transformers ; investigations are proceeding with similar equipment suitable for ratings of 1250/1500MVA for larger Grid supply points in heavily industrialised areas. Three new designs of " packaged-type " 33kV, 1000MVA, 2000A outdoor units for use at Grid supply points reached an advanced stage of development. The majority of post-war 132kV, 2500MVA circuit breakers have now been, or are in the course of being, uprated to 3500MVA.

Three trial installations of short-circuit breakers on 33kV systems were commissioned, and preliminary tests were satisfactory ; their performance in service had however not been precisely ascertained, because very few faults occurred on the circuits in question.

Transformers.—Work proceeded on 400kV/275kV, 400MVA auto-transformers ; voltage regulating facilities for these units will be provided by a new fully-insulated, on-load tap-changer, at the 275kV line end of the winding, the tap-changer forming the 275kV line termination. Preliminary design work started on transformer requirements for the future 400kV system ; auto-transformers with ratios and ratings of 500MVA, 400kV/275kV and 240MVA, 400kV/132kV are envisaged, although larger sizes may be required. Voltage-regulating facilities may not be necessary for units with a ratio of 400kV/275kV, but will be required for those with a ratio of 400kV/132kV. To meet future needs for reactive compensation, a standard specification was issued in connection with 275kV/123kV, 180MVA auto-transformers, covering provision of a delta-connected winding capable of supplying a 60MVA synchronous-condenser load at a nominal voltage of 13kV. An order was placed for a spare 275kV/132kV, 180MVA auto-transformer, designed to be within the 150 ton gross limit on the transport of heavy loads by road, and special features are being incorporated to reduce installation times.

A contract was placed for 275kV cables at Trawsfynydd covering four circuits each of 153MVA capacity, and one of 320MVA capacity, all approximately 200 yards in length ; further 275kV installations of greater length and capacity are under negotiation. There was a marked expansion of 132kV cable work.

All these major cables are oil-filled, and the majority are cross-bonded installations ; some are of the corrugated aluminium sheath type, protected by an extruded PVC sheath to extend experience with these materials.

The four towers for the 275kV River Thames crossing (West Thurrock–Northfleet) were completed and, in the light of knowledge gained from the studies on the River Severn crossing the conductors for this project are being modified to have a smooth exterior.

The design work for the new 400kV quadruple-conducting double-circuit line, having a maximum thermal capacity of 1800MW per circuit, was completed and a specification prepared ; the 132kV, 275kV and 400kV overhead line specifications were revised and the Board's approved standards for insulation were modified to incorporate new standard specifications covering insulator components at voltages from 132kV to 400kV.

Research

Research on combustion conditions includes laboratory and pilot-plant experiments and work in power stations, with the general aim of making it possible to build boilers with smaller combustion chambers.

Full-scale power station oil burners are being tested in a pilot rig ; the objects are to improve the design of burners, to reduce (*a*) the amount of excess combustion air, (*b*) sulphuric acid attack in the boilers, and (*c*) the amount of sulphur trioxide in flue gases. Two coal-burning rigs, nearing completion, will be used to study coal-burning systems over a wide range of operating conditions, and special attention is being given to deposition and corrosion in superheater steels at temperatures between 1050 deg. and 1300 deg. Fah. and to combustion at temperatures above the melting point of the ash. Knowledge is being accumulated on the direct effects of changes in fuel and firing conditions on boiler flames, and on the probable effects of those changes on boiler fouling and maintenance. Newly developed techniques are being used to study the behaviour of fuel ash, including the volatilisation, condensation, and fusion properties of the inorganic constituents.

Further uses for pulverised-fuel ash are being studied. Grants were made to the Building Research Station to continue work on pelleting and sintering pulverised-fuel ash for use as a lightweight concrete aggregate. At Glasgow University, basic work is being done in association with the South of Scotland Electricity Board on the physical properties of pulverised-fuel ash and their relation to its use as a " fill " material in road construction. The D.S.I.R. Warren Spring Laboratory has been investigating, on the Board's behalf, methods of separating iron from pulverised-fuel ash, and has produced a concentrate containing 47 per cent iron.

The reclamation of ash-dumps, and their conversion into productive arable land continued to receive special attention. Cereal and root crops were successfully grown in several places on fields of experimentally treated ash from power stations. The tolerance of plants to certain trace elements found in p.f. ash, and methods of reducing the effects of some of them which arrest or prevent normal plant growth, were investigated by university research workers supported financially by the Generating Board at Leeds and Birmingham Universities.

Steam Raising and Use.—Work on the theory and practice of advanced steam raising plant has been directed towards higher steam temperatures, because, in general, the higher the steam temperature the more efficiently the energy stored in the steam can be used. The experimental high-temperature superheater designed to study the Field cycle is being used to provide information on combustion and heat-transfer in pulverised coal flames, and to heat steam to higher temperatures than is possible in existing boilers. Preliminary investigations of flame temperatures and emissivity in a water-cooled chamber were completed in the Field cycle rig. When the superheater has been reconstructed with tubes and headers of high-temperature alloys, a further series of trials will be carried out. Tests on various steels designed to withstand high temperatures were continued at power stations, together with laboratory studies of the formation of

corrosive deposits on the fire side of superheaters, and an extensive programme of research on materials was started. A complementary study was started on the economics of using expensive materials to withstand high temperatures in advanced superheater designs.

Generation.—Power station plant design and development in recent years has concentrated on progressively larger and more powerful units, but further substantial increases in operating temperatures may not be practicable with conventional designs. An alternative means of improving efficiency would be to produce gas from coal for use in combined thermal cycles. For example, the gas could be burnt in a gas turbine and the exhaust could be used in the combustion of the fuel residue to raise steam in plant at the present range of temperatures. Detailed design studies of plant of this type have been started, together with the associated engineering experimental work.

Economic methods of storing power would be extremely valuable to the Board, and the possibility of storing energy in the form of compressed air has been suggested in several countries. The Board has made preliminary economic and technical feasibility studies which show that a scheme to compress air during off-peak periods, and to use it, in gas turbines coupled to electrical generators. during peak periods might ultimately help to economise in capital costs. Design studies have begun on this investigation.

The economic and technical possibilities of several direct-generation processes, which may be of long-term interest, are being studied. The fuel cell, which converts chemical (fuel) energy directly into electricity, in principle enables higher thermodynamic efficiencies to be attained than is possible in existing heat engines. It is probably necessary for the fuel in the cell to be a gas, so that this research is linked with that on gasification mentioned above. In magneto-hydrodynamic (MHD) generation, an electrically conducting gas is passed through a magnetic field and its energy is converted into electricity. The main problems arise from the high temperatures (2000/3000 deg.) which may be necessary, and from the extraction of electrical energy into an external circuit. Thermionic generation, in which electrons are transferred from a hot cathode surface to a cooler anode across an evacuated space, is also being studied. Problems include the nature and behaviour of the electrode surfaces, securing an acceptable life for the materials, and engineering difficulties. Thermo-electric generation has also been examined, but the prospects do not look sufficiently promising to justify experimental work by the Generating Board.

Some of these direct-generation methods, particularly MHD and thermionic generation, operate at such high temperatures that their "waste heat" is hot enough for steam raising; schemes to combine them with conventional power station plant to generate electricity at increased overall efficiency are therefore being considered.

Nuclear Research.—Research carried out in the Board and United Kingdom Atomic Energy Authority Laboratories showed that a significant improvement in the life of fuel-element cans is likely if a magnesium-zirconium alloy (ZA) is used instead of the magnesium alloy (A12) can supplied to the first reactors. The operational performance of the new alloy will be assessed in reactors.

Work to improve the efficiency of nuclear power station heat-exchangers included measuring the heat-transfer and pressure-drops in typical sections of the Bradwell and Berkeley type heat-exchangers.

At Leatherhead, work on the kinetic behaviour of nuclear reactors included experiments on a simulated rig on which the response-time of the channel-outlet thermocouple assemblies, was measured, and the causes of uneven heating of fuel cans were investigated.

In co-operation with the United Kingdom Atomic Energy Authority, the long-term behaviour of materials under irradiation has been examined, with particular attention to the way in which irradiation can accelerate creep-relation effects in graphite, iron, and zirconium. Other work concentrated on the reactions between graphite and carbon dioxide, and on changes in the mechanical properties of graphite at various stages of oxidation. A large number of graphite samples were prepared and their physical and chemical properties measured in preparation for their insertion in reactors; changes in these properties will be monitored over the years of operation.

The Board's computers were engaged upon a considerable amount of mathematical analysis and calculations on fault "simulation" studies. The IBM 709 digital computer and "PACE" analogue computer were extensively used to study the expected behaviour of nuclear reactors and their control systems under the whole range of operating conditions. Preliminary results were obtained on the detailed steady-state distribution of power in a large-diameter reactor core. A two-dimensional programme developed by the United Kingdom Atomic Energy Authority staff for the IBM 709 computer was used to predict the disturbances in power and in the distribution of fuel temperature caused by control-rods and flattening-absorbers; the best distribution of such absorbers can be determined from the predictions.

Transmission.—As a result of the Board's decision to raise the main transmission voltage to 400kV, the programme for high-voltage research was revised to fill existing gaps in knowledge of 400kV systems, and to plan for research on systems designed to work at considerably higher voltages.

Information is now almost complete on the requirements of outdoor insulation for 400kV lines, plant and equipment subjected to industrial pollution, and an extension of the insulator-testing facilities at Brighton is being planned to deal with 400kV and high-voltage systems exposed to salt sea-spray. A new double-circuit, single-phase, experimental test line was designed for operation at Leatherhead at voltages up to 840kV for studies of corona loss and radio interference.

A complex engineering problem arose from the effects of wind on the conductors of the Severn Crossing. This span is the sixth longest in the world and uses 1·7in diameter conductors (believed to be the largest in the world), which are strung with a normal vertical separation of 27ft between conductors. Under certain wind conditions, the conductors oscillate so far vertically that they pass each other in mid air. In weather conditions causing severe oscillation, clearances are reduced to the point where short-circuits occur and the lines are automatically put out of service by protective gear. This form of oscillation is well known when there is ice on the conductors, but very rarely occurs on lines in this country when there is no ice present. Investigations to ascertain the precise cause of the trouble and how to prevent it, are in hand in order to safeguard the Severn and other long crossings. Theoretical studies of the dynamics and aerodynamics of overhead line structures have been accompanied by model work under contract at Imperial College, London, and by direct observations by research staff and by cameras synchronised with the faults at the Severn crossing. Results are incomplete, but have enabled recommendations to be made for modifications to the design of conductors for the Thames crossing at Northfleet.

The Board is pursuing a long-term study to find out to what extent automatic control can be applied to power station and Grid control. Information is being collected about the operation of the system so that it can be expressed in terms that automatic machines can handle, i.e. numerically, to ensure that any partial automatic control that may be introduced is consistent with manual control. This study includes tests of the response to disturbances of the whole system of interconnected generators, and analyses of the test data. Another part of the investigation concerns the provision of additional information analysed and presented in such a way as to make manual control easier for operators or more precise. An operational aid now being constructed for installation at the end of 1961, is a device for assessing automatically and continuously the "security" of the pattern of power flow through the 275kV network. This device displays continuously what the effect would be on a sector of the supply system of cutting out any given line, and so indicates to the operator where there is a risk of other lines becoming overloaded if any one of them becomes unserviceable. The application of the Board's IBM 709 computer as an aid to system operation is also being studied.

Another project is a trial under actual operating conditions of a system to control generating plant by means of an automatic computer at a Grid control centre. To avoid extensive experiments on the Board's Grid system, an electronic "model" of part of the system is being designed for various possible control schemes to be tried and sufficient reliability ensured before any operational trial is undertaken. Other studies in hand point the way to experimental installations in power stations to make the generating plant obey the commands of the Grid control centre computer and to "optimise" continuously the performance of individual stations. The early part of this work now in progress includes measuring and recording the transient reponse to disturbances of boilers and other steam plant.

The hydraulic transport of coal is being examined to see whether its economic and technical possibilities are of interest to the Board. By this method of transport energy is transmitted, still in the form of fuel, to the centres where it is to be used, by conveying a mixture of coal and water through pipelines. A feasibility study showed that hydraulic transport of coal to power stations in this way might have advantages, but many practical and economic aspects have yet to be examined. Two design studies have been launched: one is a hydraulic transport system for pumping coal to a large modern power station sited near a coalfield, and associated with this, plans are being made for an experimental 1 mile long pipeline to provide information on the rate of wear and corrosion in coal-transport pipes; the second design study is for a scheme to pump coal over a distance of 150 miles. The supporting experimental work seeks information on the flow of coal and water mixtures in pipes and, in particular, on the effect of different sizes of coal particles. The removal of water from the coal and the thermal drying of coal are also being investigated.

THE ENGINEER

TECHNICAL CONTRIBUTORS SECTION

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Geometry of the Inertia Circle

By R. BRAIN, M.Eng., A.M.I.C.E., A.M.I.Mun.E.*

The circle of inertia is used only infrequently for the solution of problems relating to asymmetrical bending and seldom in the form advocated in this article. General conditions for the inertia circle are examined and simple rapid geometrical constructions peculiar to this method given for the location of the Neutral Axis for any chosen plane of bending and the evaluation by scaling of the relevant second moment of area and section modulus.

IN the analysis of hyperstatic or statically indeterminate structures, the balance of equations necessary to complete solution is obtained from consideration of the stiffness characteristics of the members. Unless the sections of the members are loaded about axes of symmetry, "asymmetrical" bending occurs and the already complex problem is thus further complicated by ascertaining the relevant second moments of area and neutral axes in order to establish compatibility of deflections.

Hitherto the computation of these values has necessitated the tedious solution of a number of trigonometrical equations, even where a semi-graphical treatment has been employed.

It is hoped that this entirely graphical treatment will considerably reduce the labour involved in the solution of problems in asymmetrical bending and lead to a better appreciation of the manner in which these sections deflect.

THEORY

Assume that AA and BB are two mutually perpendicular axes passing through the centroid of the section and about which the Second Moments of Area I_{AA} and I_{BB}, and Inertia Product I_{AB} are known. To find the Second Moments of Area and Inertia Product about two similar axes PP and QQ.

$$I_{PP}=\Sigma q^2\delta_A.$$

where

$$q=b\cos\theta-a\sin\theta \quad \text{(Fig. 1)}$$

i.e.

$$I_{PP}=\cos^2\theta\Sigma b^2\delta_A+\sin^2\theta\Sigma a^2\delta_A-2\sin\theta\cos\theta\,\Sigma ab\,.\,\delta_A.$$

Now

$$I_{AA}=\Sigma b^2\delta_A.\quad I_{BB}=\Sigma a^2\delta_A.\quad I_{AB}=\Sigma ab\delta_A$$

$$I_{PP}=\left(\frac{1+\cos 2\theta}{2}\right)I_{AA}+\left(\frac{1-\cos 2\theta}{2}\right)I_{BB}-\sin 2\theta I_{AB}$$

$$=\left(\frac{I_{AA}+I_{BB}}{2}\right)+\cos 2\theta\left(\frac{I_{AA}-I_{BB}}{2}\right)-\sin 2\theta I_{AB} \quad . \quad . \quad (1)$$

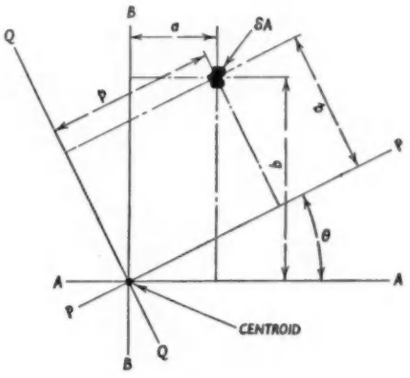

Fig. 1

I_{QQ} may be similarly derived by interchanging suffixes in Equation (1)

$$I_{PQ}=\Sigma qp\delta_A.$$

where

$$q=b\cos\theta-a\sin\theta$$

$$p=a\cos\theta+b\sin\theta$$

i.e. $I_{PQ}=\cos\theta\sin\theta\Sigma b^2\delta_A-\cos\theta\sin\theta\,\Sigma a^2\delta_A+(\cos^2\theta-\sin^2\theta)\Sigma ab\,.\,\delta_A$

$$=\sin 2\theta\left(\frac{I_{AA}-I_{BB}}{2}\right)+\cos 2\theta I_{AB} \quad . \quad (2)$$

Equations (1) and (2) are the general equations of inertia. Principal Axes of Inertia I_{UU} and I_{VV} will be defined as those axes where the Inertia Product is zero. Let the angle between axis AA and the principal

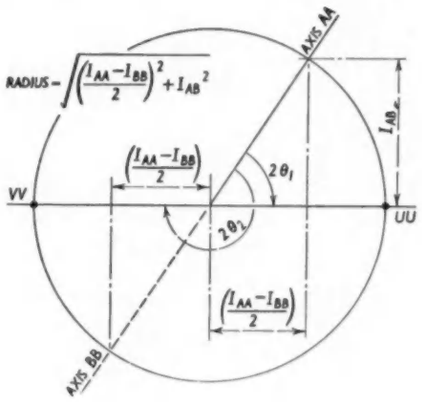

Fig. 2

axis UU be θ_1, and the principal axis VV be θ_2 i.e.

$$I_{UV}=0 \text{ or } \left.\begin{matrix}\tan 2\theta_1\\ \tan 2\theta_2\end{matrix}\right\}=\frac{-I_{AB}}{\left(\frac{I_{AA}-I_{BB}}{2}\right)} \quad . \quad (3)$$

From Fig. 2.

$$\left.\begin{matrix}\sin 2\theta_1\\ \sin 2\theta_2\end{matrix}\right\}=\frac{\mp I_{AB}}{\sqrt{\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2}}$$

$$\left.\begin{matrix}\cos 2\theta_1\\ \cos 2\theta_2\end{matrix}\right\}=\frac{\pm\left(\frac{I_{AA}-I_{BB}}{2}\right)}{\sqrt{\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2}}$$

Substituting in Equation (1) and rewriting

$$\left.\begin{matrix}I_{UU}\\ I_{VV}\end{matrix}\right\}-\left(\frac{I_{AA}+I_{BB}}{2}\right)=\pm\frac{\left[\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2\right]}{\sqrt{\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2}}$$

or

$$\left.\begin{matrix}I_{UU}\\ I_{VV}\end{matrix}\right\}-\left(\frac{I_{AA}+I_{BB}}{2}\right)=\pm\sqrt{\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

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Technical Contributors Section (*continued*)

Equations (2), (3) and (4) will be found to satisfy the equation.

$$\left[\begin{matrix}I_{UU}\\I_{VV}\end{matrix}\right\}-\left(\frac{I_{AA}+I_{BB}}{2}\right)\Big]^2=\left(\frac{I_{AA}-I_{BB}}{2}\right)^2+I_{AB}^2 \quad . \quad . \quad . \quad . \quad . \quad (5)$$

This is the equation to a circle in the form $r^2=x^2+y^2$ and is rather different from that usually given (*vide Steel Designers' Manual*) where the diameter is $(I_{UU}+I_{VV})$ instead of $(I_{UU}-I_{VV})$.

Equation (5) is plotted as Fig. 3. From

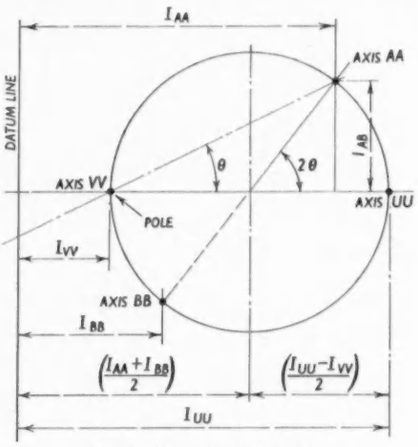

Fig. 3—The circle of inertia

Equation (3) and Fig. 2 it is apparent that one most proceed clockwise from AA an amount $2\theta_1$ on the Inertia Circle to locate the major principal axis, i.e. normal sign convention applies.

Bending About an Axis Oblique to the Principal Axes

Confusion often arises between the Plane of Bending and the Axis of Bending—these being mutually perpendicular. In the following analysis, the Plane of Bending will be assumed throughout,

Consider a Bending Moment M applied

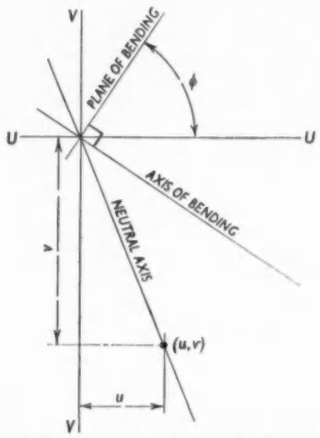

Fig. 4—Diagram showing relationship between plane of bending, axis of bending and neutral axis

in a plane inclined at ϕ to the major principal axis UU. At any point (u, v) the stress due to bending is

$$\sigma=\frac{M_U\cos\phi}{I_{VV}}+\frac{M_V\sin\phi}{I_{UU}}$$

This may be written as

$$\frac{\sigma}{M_U}=\frac{1}{Z_U}=\frac{\cos\phi}{I_{VV}}+\frac{\sin\phi}{\left(\frac{U}{V}I_{UU}\right)} \quad . \quad . \quad (6)$$

where Z is the effective Section Modulus of the point (u, v).

Equation (6) will be recognised as that of a straight line in the polar form

$$\frac{1}{r}=\frac{\cos\phi}{h}+\frac{\sin\phi}{k}$$

where h and k are the intercepts of the straight line on the VV and UU axes respectively and r is the radius vector inclined at ϕ to the UU axis joining the origin to the straight line.

Condition for the Neutral Axis

If the point (u, v) lies on the Neutral Axis then $1/Z=0$.

i.e.

$$\frac{\cos\phi}{I_{VV}}=-\frac{\sin\phi}{\frac{u}{v}I_{UU}}$$

i.e.

$$\frac{v}{u}=\tan\theta=-\frac{I_{UU}}{I_{VV}}\cot\phi \quad . \quad . \quad (7)$$

where θ is the inclination of the Neutral Axis to the Major Principal Axis for bending in a plane inclined at ϕ to the UU axis.

Geometric Constructions

Draw out the section to scale, locate the centroid C and the principal axes of inertia and set out on the major principal axis of inertia to some suitable scale I_{VV} to the left of the centroid at B and $(I_{UU}-I_{VV})$ to the right of the centroid at A. Bisect the length $(I_{UU}-I_{VV})$ at 0 and with CA as diameter describe the Inertia Circle.

The centroid C is now the Pole and any Neutral Axis drawn through this point will intercept the Inertia Circle at the correct scale measure of the appropriate Second Moment of Area.

(*a*) Section Modulus

Choose any probable critical point (u, v), Fig. 5, and draw a line through C and (u, v) to cut the Inertia Circle at D. Join AD and produce this line to cut the Datum line at E. Then $EB=\frac{u}{v}.I_{UU}$.

Transfer E to F on the VV axis and set

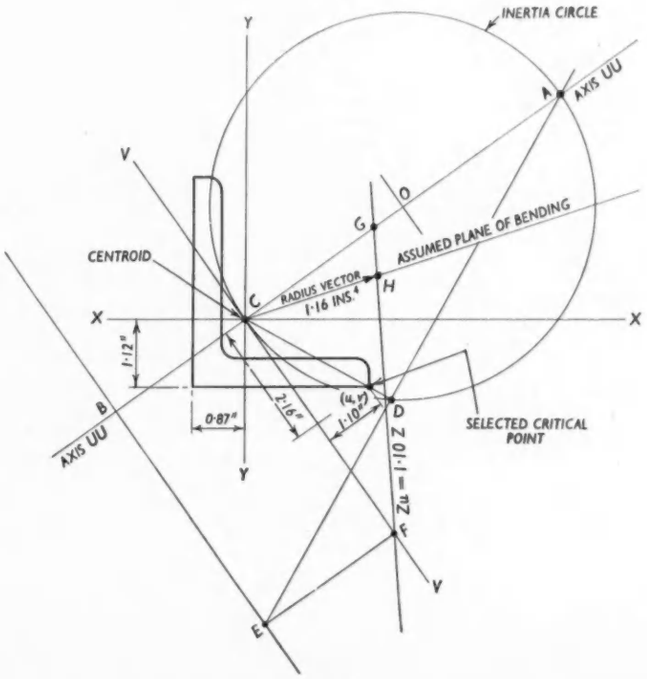

Fig. 5

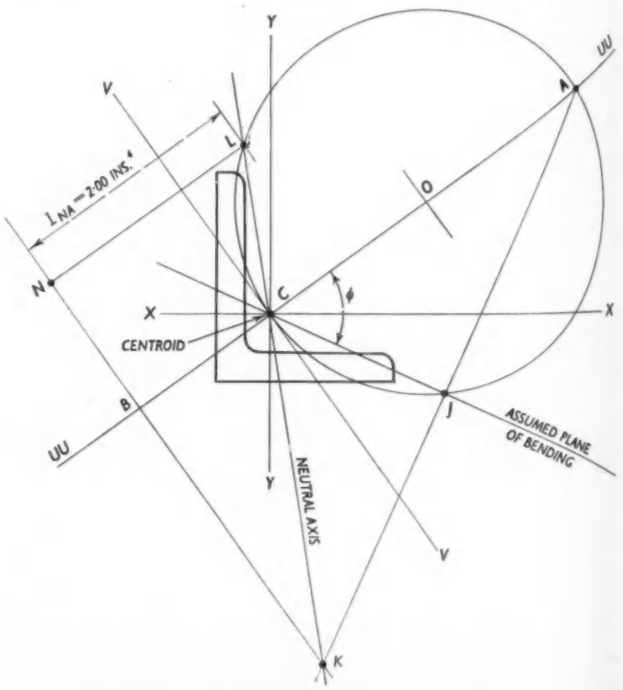

Fig. 6

off G on CO such that $BC=CG=I_{VV}$. Join FG.

Then FG is the straight line referred to in Equation 6 and the radius vector has the magnitude Zu to the same scale as the Inertia Circle.

(*b*) NEUTRAL AXIS

Draw the plane of bending through C to cut the Inertia Circle at J. Produce AJ to K. Join KC—then KC produced is the Neutral Axis.

Proof.

$$KB=I_{UU}\cot\phi \quad BC=I_{VV}$$

$$\text{Slope of } KC=-\frac{I_{UU}}{I_{VV}}\cot\phi$$

The distance LN is the scale magnitude of the Second Moment of Area about the Neutral Axis.

Example.—Figs. 5 and 6 show a 3½in by 3in by ¼in B.S.U.A. subjected to oblique bending—a different plane in each case. $I_{UU}=4{\cdot}55\text{in}^4$. $I_{VV}=1{\cdot}33\text{in}^4$ $\alpha=\tan^{-1}0{\cdot}71$.

In Fig. 5 the right-hand toe is taken as the critical point and the appropriate Zu line FG constructed as above. Then the radius vector CH is obtained by drawing the Plane of Bending through the centroid to intercept the Zu line.

In this case the scale value of the radius vector Zu is $1{\cdot}16\text{in}^4$ and the magnitude of U is 1·10in, i.e. Effective Section Modulus for the selected critical point

$$Z=\frac{1{\cdot}16}{1{\cdot}10}=1{\cdot}05\text{in}^3$$

The Zu line is similar to the Z polygon, but the factor "u" has been introduced of necessity to correct dimensionally for the diagram, since different "u" values may apply to different parts of the section the Zu polygon must be used with discretion. In Fig. 6 the assumed Plane of Bending produces a Neutral Axis KCL; in this case the distance NL is 2·00in. The section modulus may be obtained for any point by dividing this value by the linear scale distance from the Neutral Axis.

Fig. 6 is probably of most value as the direction of deflection is also readily ascertained (normal to the Neutral Axis) whilst Fig. 5 is of value largely for predicting which orientation of the section will give rise to maximum bending stresses (normal to the Zu line. For sections which are likely to be used often, the Inertia Circle may be drawn on the section and transparent overlays used for successive positions of the section in determining the relevant Neutral Axes.

REFERENCE

Steel Designers' Manual, Second edition, 1960, Crosby Lockwood and Son, Ltd., London.

On the Meaning of Unified Equations Related to Weirs for Measurements of Open Channel Flow

By F. V. A. ENGEL* and W. STAINSBY†

Unified flow equations applicable to sharp-crested weirs, broad-crested weirs, and Venturi weirs comprise a common velocity-of-approach factor as a separate term. The contraction phenomenon of the nappe distinguishes the sharp-crested weir from other weir types. Both the velocity-of-approach factor and the contraction coefficient can be derived from first principles. These problems have been dealt with in two parts in the present investigation. Discharge coefficients are defined by the unified weir equations and analysed by means of non-dimensional groups of dynamics. This procedure determines the range of applicability of "constant" discharge coefficients for specified accuracy limits.

MEASUREMENT of fluid flow in closed conduits has advanced considerably during the last thirty years as most authorities now apply a common pattern of flow equation for orifices, nozzles, and Venturi tubes. If the velocity-of-approach is separated and expressed as a specific factor, two distinct discharge coefficients of approximately 0·61 for orifices, and 0·98 for nozzles and Venturis are found to be applicable over a considerable range of area ratios. The low value of 0·61 reflects the contraction of the submerged jet issuing from the aperture of the orifice plate. An empirical discharge coefficient is used with flow equations to cover various aspects of fluid dynamics and in particular viscosity influences. Usually, the discharge coefficient characteristics are presented on the basis of the Reynolds number. The common flow equation was derived from first principles, the Bernoulli theorem, referring to non-viscous and irrotational flow conditions. All attempts have failed to establish the contraction coefficient on strict mathematical reasoning, even for the simple case of three-dimensional liquid flow through a circular orifice into atmosphere. The only paper known to the authors on this subject by E. Trefftz[24] presented a method of approximation introducing as a first step an empirical element, namely the contour of the jet. The problem to be solved in connection with flow measurement in closed conduits is more specific as it refers to a surmerged jet issuing into a limited space characterised by the area ratio. In the various National Standards on flow measurement in closed conduits by means of orifices, nozzles, and Venturis numerical values of the discharge coefficients were presented with close tolerances valid beyond certain "constancy" limits. In view of contraction or separation stringent conditions on dimensions and locations of the tapping points have to be observed.

Progress in establishing a common type of weir equation, at least for two representative designs, the full-width, sharp-crested weir, and the Venturi weir has been seriously handicapped by the way in which many authorities have established flow equations valid over limited ranges and related only to some specific features of their particular investigation. As a typical example we refer to the Rehbock-1913-equation, namely:

$$C=\underset{\substack{\text{basic}\\\text{contraction}\\\text{coefficient}}}{0{\cdot}605}+\underset{\substack{\text{combined}\\\text{velocity-of-}\\\text{approach}\\\text{influences}}}{0{\cdot}08\frac{h}{w}}+\underset{\substack{\text{Weber and}\\\text{Reynolds}\\\text{number}\\\text{influences}}}{\frac{1}{1000h}} \quad \ldots\ldots (1)$$

The second term is a function of the area ratio, as

$$\frac{h}{w}=\frac{h/(h+w)}{1-h/(h+w)} \quad \ldots (1a)$$

It should be understood that this term in the Rehbock equation combines two different area ratio influences. The first is concerned with the variation of the contraction coefficient with the area ratio. The second is related to the velocity-of-approach factor as defined by the Bernoulli theorem. These are two distinct physical phenomena. Unfortunately, this fact had been overlooked. The situation occurs in the works of Bazin, Rehbock, and other authorities, who assume a constant value for the contraction coefficient. They recommend a contraction coefficient close to the value established on theoretical lines by Kirchhoff, namely 0·611. Their policy may be responsible for the neglect of the extensive investigations by M. Réthy,[22] R. von Mises,[20] and other authorities, who presented on exact mathematical lines the variation of the contraction coefficient over the complete range of area ratios from 0 to 1. For this reason the variation of the velocity-of-approach specified by a separate factor, covering the same range of area ratios, was not considered by these authorities. Unified weir equations, recently established by the authors should have been developed many years ago.

Numerical values and terms lumped in the discharge coefficient were allocated at random to various features. No consistent representation was accepted and the final results established by those authorities often differ considerably, which makes a re-assessment or analysis of discharge characteristics either cumbersome or impossible. Incomplete relations were adopted, resulting in dimensionally incorrect terms. Finally, these discharge coefficients were attached to flow equations, which were based on unsound mathematical assumptions. Unfortunately, without due explanation these relations are recommended for general use in most textbooks on fluid mechanics and on hydraulic engineering.

The issues become even more involved by statements which stress the effects of curvilinearity upon the critical depth relationships developed for parallel flow and ignoring publications on this subject by C. Jaeger.[11, 12] However, the most serious omission in textbooks is that they do not refer at greater length to the basic weir relations published by A. H. Jameson[13] in 1930. Its general form is "applicable to all shapes of inlet and throat when the discharge is a maximum." On the basis of a postulate by C. Jaeger the Jameson weir flow equation may be rightly extended to full-width, sharp-crested weirs. Again, recent publications have shown that the implications of the investigations both by Jameson and Jaeger are not yet fully understood. A paper by F. Eisner[3] (1933), in which the Froude number was introduced as the crucial non-dimensional group related to weir flow problems, appears to have remained unnoticed. Some of the problems on weir flow have not yet been settled, in spite of the work of scientists and engineers covering a period of nearly 250 years.

The authors hope to stimulate once again

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Technical Contributors Section (*continued*)

interest in the problems of weir flow, and try to assist the engineer to appreciate a more rational approach to the subject. This article should also offer a challenge to the applied mathematician whose contribution may finally elucidate all problems involved.

In Part I the meaning of the velocity-of-approach with regard to the Bernoulli theorem will be given and its influence on the variation of the contraction coefficient will be presented in Part II. The discharge coefficient not including the contraction coefficient and the velocity-of-approach factor will be analysed in the last Part III of the article.

The unified weir equations introduced by the authors should avoid some misconceptions which occurred previously. The coefficients defined by the unified weir equations may explain two paradoxes, one, occurring in the Rehbock equation with a discharge coefficient for zero flow approaching infinity ; the other, when the discharge coefficient established by von Mises becomes infinitely large for an area ratio approaching unity, i.e. under conditions when no constriction exists. The main intention of the authors is to assist the engineer to appreciate a more rational approach to the subject. From the practical point of view unified weir equations and their related discharge coefficient characteristics should indicate ranges of improved measuring accuracy and limits of applicability. Finally, these equations can be used in the selection of the most suitable type of weir on the basis of backwater effects.[23]

Part I.—Unified Weir Equations

In hydraulic engineering, empirical relations have persisted to such an extent that coefficients entering equations as basic terms are taken as a proof that the relation is not in line with exact theory. This, however, is not a necessary conclusion. A term, which we may call a coefficient, can well be established from first principles and no empirical element need enter the whole process of its mathematical derivation. If empirical terms occur in the basic flow equations an uncertainty is introduced, which is an unwanted factor particularly with accurate measurements. Therefore, the authors have established unified weir equations[6, 7] in which all component terms are derived from first principles. They are basic equations in full accord with theory. The authors call the equations " unified," as the same pattern of relation is applicable to both sharp-crested weirs and long structures. Some comments on the author's 1958 publications show that these facts are not yet fully understood.

A. H. Jameson[13] has shown that the general flow equation—similar to the standard equation of Venturi tubes, but with A_1 and A_2 as variable areas of upstream and throat sections and based on the Bernoulli theorem—is the prerequisite in establishing a general flow equation of all kinds of weirs under freely discharging conditions. This equation is :

$$Q=\frac{A_2}{\sqrt{1-(A_2/A_1)^2}}\sqrt{2g(h_1-h_2)} \quad . \quad (2)$$

Differentiating this relation with respect to the variable head h_2 in the throat and equating to zero gives the condition for maximum flow. In case of a rectangular channel cross section and also a rectangular contracted section a cubical equation is obtained for the crucial dimensions of heads, widths, and the area ratio, namely :

$$x^3-[3x-2]\,(b_1/b_2)^2\,[(h_1+w)/h_1]^2=0 \quad . \quad (2a)$$

where

$$x=h_2/h_1 \quad . \quad . \quad . \quad . \quad (2b)$$

The general flow equation is

$$Q=x^{3/2}\,b\sqrt{g}\,h_1^{\,3/2} \quad . \quad . \quad (3)$$

In this equation the term x should be considered as an entity. To obtain a common pattern of flow equations for both types of weirs, sharp-crested weirs as well as long structures, the velocity-of-approach factor is given in a slightly changed version, namely :

$$C_{va}=(3/2)^{3/2}\,x^{3/2} \quad . \quad . \quad (4)$$

Inserting this term into equation (3) gives

$$Q=(2/3)^{3/2}C_{va}b\sqrt{g}\,h_1^{3/2} \quad . \quad (5)$$

For the full width, sharp-crested weir the width $b=b_1$, which is the width of the channel. For Venturi weirs $b=b_2$, i.e. the throat width. Accordingly the area ratio included in equation (2*a*) becomes a width ratio b_2/b_1 for Venturi weirs without a sill ; a depth ratio $h_1/(h_1+w)$ for full width, sharp-crested weirs and broad-crested weirs. These terms eliminate any reference to the " critical " or " control " section which for free discharge conditions must occur somewhere in the contracted water stream. The more important dimensions characterising both types of weirs are schematically illustrated in Figs. 1(*a*) and 1(*b*).

The next step is to establish a more specific relation than equation (5) for the sharp-crested weir. It should be understood that these steps are not a mathematical proof but merely indicate why the authors recommended a convention, namely introducing the terms $C_e\sqrt{3}$ into the weir equation.

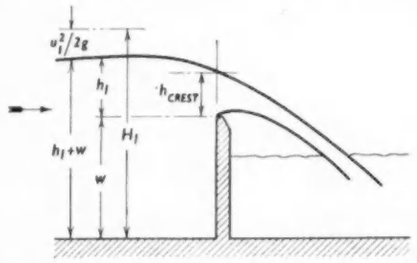

Fig. 1(*a*)—General layout of a sharp-crested weir with characteristic dimensions

The basic equation (3) may be re-arranged in the following way

$$Q=bxh_1\sqrt{gxh_1} \quad . \quad . \quad . \quad . \quad (6)$$

The product of the first two terms on the right-hand side is replaced by the area of the nappe by writing $b=b_1$ and eliminating $x\,h_1$ by h_2. In view of the contraction $C_e\,b_1\,h_2$ becomes the effective area of the control section where C_e is the coefficient of contraction. Therefore,

$$Q=C_eb_1h_2\sqrt{g}xh_1^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (7)$$

Re-introducing $x\,h_1$ for h_2 gives

$$Q=C_eb_1x^{3/2}\sqrt{g}h_1^{3/2} \quad . \quad . \quad . \quad . \quad (8)$$

and analogous to equation (5) gives

$$Q=(2/3)^{3/2}C_{va}C_eb_1\sqrt{g}h_1^{3/2} \quad . \quad (9)$$

The final equation for sharp-crested weirs recommended by the authors is obtained by inserting the numerical factor $\sqrt{3}$ into the right-hand side of the equation. The reason for this is to bring the numerical values of the Weisbach-Francis equation into line with the general flow equation (5). This step appears to be permissible in spite of some critical remarks referring to the mathematical procedure applied when deriving the Weisbach equation, which is

$$Q=(2/3)C_c\sqrt{2g}\,b\left[\left(h+\frac{u^2}{2g}\right)^{3/2}-\left(\frac{u^2}{2g}\right)^{3/2}\right] \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Multiplying

$$(2/3)C_c\sqrt{2g} \text{ by } \sqrt{3}/\sqrt{3}$$

gives

$$(2/3)^{3/2}C_c\sqrt{3}\sqrt{g}$$

Therefore, the final set of equations for both types of weirs reads as follows :

Sharp-crested weirs :

$$Q=(2/3)^{3/2}C_{va}C_c\sqrt{3}\sqrt{g}b_1h_1^{3/2} \quad . \quad (11)$$

Venturi weirs :

$$Q=(2/3)^{3/2}C_{va}\sqrt{g}b_2h_1^{3/2} \quad . \quad . \quad (12)$$

The adopted procedure is one of convenience. The various steps introduced to establish unified weir equations refer to analogous basic terms in equations (11) and (12). No empirical element has been taken into consideration. In particular both the contraction coefficient C_e as well as C_{va} can be obtained on the basis of mathematical procedures. It has already been shown for C_{va} and will be dealt with at greater length for C_e in the following sections and in the Appendix.

Admittedly the derivation of the equation for sharp-crested weirs does not follow the same outlines as presented for long structures. In view of the existence of a contraction coefficient this may appear impossible. Some authorities are of the opinion that flow features for long structures differ considerably from those prevailing over short structures. They do not accept that the " theorem of minimum," by Boussinesq, referring to steady flow in open channels, is of more general application than the principle by Bélanger, as dealt with in various publications by C. Jaeger. Some authorities assume that the principle of Bélanger is applicable only to long structures with straight parallel stream lines and a uniform distribution of velocity over the whole flow section. However, Jaeger has shown that this principle is applicable to any kind of flow in open channels, whatever the velocity distribution and the curvature of the stream lines. Jaeger[11] states

" Unless the conditions at the boundaries are expressly opposed to it, every open channel

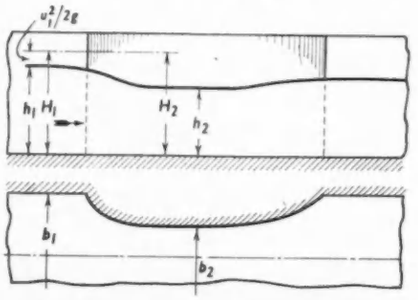

Fig. 1(*b*)—General layout of a Venturi weir with characteristic dimensions

flow possesses at least one critical point somewhere along its course and the discharge of the system is, therefore, a maximum.

"If a critical point exists the flow is called 'non-submerged' and it is independent of the tail water; if not, it is submerged flow, dependent on the tail water."

These remarks justify the procedures adopted by the authors[6, 7] when establishing a common pattern of weir flow equations. It should be noted that Bleines[1] applied in his investigation of a flow equation for sharp-crested weirs the postulates established by Jaeger.

The coefficient of contraction investigated by many authorities (Part II), mainly enlarging upon the original investigation by Kirchhoff, is based on the method of conformal transformation.

F. Eisner[3] has analysed in a comprehensive way the various steps taken by von Mises[20] in determining the discharge coefficient of sharp-crested weirs. This coefficient is applicable only to a flow equation which does not explicitly or implicitly include any velocity-of-approach term related to the head as will be shown.

Commencing with the flow equation

$$Q=ub(h+w)$$

and introducing the following substitution

$$z=u/\sqrt{2gh}$$

we obtain

$$Q/b=(z/y)\sqrt{2g}h^{3/2} \quad . \; . \; . \quad (13)$$

where

$$y=h/(h+w) \quad . \; . \; . \; . \quad (13a)$$

i.e. the area ratio (note: Eisner uses x instead of y; however, in our investigation x is already used in connection with the velocity-of-approach term in the Jameson equation).

The main feature of equation (13) is that the velocity-of-approach factor has been eliminated from the term referring to the head to be measured over the crest of the weir. The velocity-of-approach influence is represented by the terms in the square brackets in the following equation

$$Q/b=\frac{2}{3}C_c[(1+z^2)^{3/2}-z^3]\sqrt{2g}h^{3/2} \quad . \; . \; (14)$$

which is obtained from the Weisbach equation

$$Q=\frac{2}{3}C_c\sqrt{2g}b\left[\left(h+\frac{u^2}{2g}\right)^{3/2}-\left(\frac{u^2}{2g}\right)^{3/2}\right]$$

$$. \; . \; . \; . \; . \quad (10)$$

after substituting

$$z=u/\sqrt{2gh}$$

From equations (10) and (14) we obtain a relation from which z can be determined, namely:

$$\frac{z}{y}=\frac{2}{3}C_c[(1+z^2)^{3/2}-z^3] \; . \; . \quad (15)$$

or

$$yC_c=\frac{3}{2}\frac{z}{(1+z^2)^{3/2}-z^3} \quad . \; . \quad (15a)$$

Introducing the discharge coefficient C_d into equation (13) we obtain

$$Q/b=\frac{2}{3}C_d\sqrt{2g}h^{3/2} \quad . \; . \; . \quad (16)$$

where

$$C_d=\frac{3}{2}(z/y)=C_c[(1+z^2)^{3/2}-z^3]$$

$$. \; . \; . \; . \quad (16a)$$

Some confusion may occur as von Mises has established two coefficients, the contraction coefficient C_c and the discharge coefficient C_d. The following investigation will show, however, that the coefficient of discharge C_d is not applicable to the unified weir equation (11).

Equation (14) should be multiplied by $\sqrt{3}/\sqrt{3}$ to bring it in line with weir equation (11). Re-arranging equation (14) gives

$$Q/b=(2/3)^{3/2}C_c\sqrt{3}[(1+z^2)^{3/2}-z^3]\sqrt{g}h^{3/2}$$

$$. \; . \; . \; . \quad (17)$$

It should be compared with equation (11)

rewritten as $Q/b=(2/3)^{3/2}C_c\sqrt{3}C_{va}\sqrt{g}h^{3/2}$

0·7 and unity it is obvious that the values in column (ix) deviate considerably from the combined coefficients, column (x). It should be noted that the C_{va} values approach 1·837, i.e. a finite value for conditions when both the area ratio and the contraction coefficient approach unity. This shows clearly the difference between equations (11) and (17), and in particular the restricted meaning of equation (17). Equation (11) was derived from first principles, while equation (17) is derived from the Weisbach equation with all its limitations. A. Lauck[19] has drawn atten-

TABLE I—*Coefficients given by von Mises, Equation* (16*a*), *Compared with Velocity-of-Approach Factor* C_{va} *and Combined Coefficients Defined by Equation* (11).

Depth ratio $h/(h+w)$ (i)	z (ii)	$(1+z^2)^{3/2}$ (iii)	z^3 (iv)	$(1+z^2)^{3/2}-z^3$ (v)	C_{va} (vi)	C_c (vii)	Discharge coefficient $C_d=C_c[(1+z^2)^{3/2}-z^3]$ (viii)	$C_c\sqrt{3}$ (ix)	Combined coefficient $C_{va}\,C_c\sqrt{3}$ (x)
0	0	1·0	0	1·0	1·0	0·611	0·611	1·058	1·058
0·1	0·04	1·0024	0·00006	1·0023	1·0022	0·612	0·614	1·063	1·062
0·2	0·0826	1·0104	0·00057	1·0098	1·0092	0·616	0·622	1·077	1·077
0·3	0·1276	1·0247	0·0021	1·0226	1·0209	0·622	0·636	1·102	1·10
0·4	0·1756	1·0468	0·0055	1·0413	1·0387	0·6315	0·656	1·136	1·135
0·5	0·2290	1·0786	0·0120	1·0666	1·0636	0·644	0·687	1·190	1·188
0·6	0·2940	1·1317	0·0254	1·1063	1·0979	0·662	0·735	1·273	1·259
0·7	0·3724	1·214	0·0515	1·1625	1·1466	0·687	0·800	1·386	1·364
0·8	0·4856	1·374	0·1148	1·2592	1·2188	0·722	0·911	1·578	1·524
0·9	0·682	1·773	0·3172	1·4558	1·3401	0·781	1·138	1·971	1·813
1·0	∞	∞	∞	∞	1·8372	1·0	∞	∞	3·182

Values of column (ii) are taken from F. Eisner[3] (Table 3, page 30).

Table I was compiled to demonstrate the implications of some of the terms given in equations (11) and (17). The term in square brackets, equation (17) has been calculated (column (v)), on the basis of an auxiliary value z as given by Eisner.

The main purpose of the following analysis is to show that only C_c is applicable to the unified weir equation (11). The discharge coefficient C_d should not be used as it includes the velocity-of-approach factor. For large area ratios its numerical values clearly demonstrate some weakness of its origin, namely the Weisbach equation. For small area ratios, say even up to 0·5, both terms

$$C_{va} \text{ and } (1+z^2)^{3/2}-z^3$$

differ less than one-third of 1 per cent. For area ratios up to 0·4 the last term z^3 in the square bracket is less than 0·55 per cent of

$$(1+z^2)^{3/2}.$$

Nevertheless, the latter term is a better approximation to the velocity-of-approach factor in the unified weir equation, than terms like

$$[h/(h+w)]^2$$

which were included in weir coefficients by Bazin and the S.I.A. Standards. It must be emphasised that C_{va} was derived on the maximum flow principle and is not adequately represented by a simple relation like the square of the area ratio.

The figures in Table I reveal another shortcoming of the discharge coefficient C_d given by von Mises. Whilst in general for accurate flow measurement medium area ratios say up to 0·6 are recommended, the trend of the numerical values when approaching large area ratios may indicate the soundness or the fallacy in deriving those values. In the unified weir equations C_{va} has a finite value for an area ratio of unity, i.e. the case if there is no constriction in the channel. In contradistinction the discharge coefficient C_d or the value z in the von Mises equations becomes infinitely large for an area ratio of unity. In equation (17) the term in the square bracket also becomes infinite for $z\to\infty$, which results from equation (15).

Considering the fact that the discharge coefficient C_d increases rapidly from 0·8 to infinity for a range of area ratios between

tion to two incorrect assumptions in the derivation of the Poleni or Weisbach equation, namely:

(*a*) the fluid layers discharge independently over the weir;

(*b*) the full head h_1 is used as integration limit, while the upper surface of the nappe in plane of the upstream face of the weir plate is considerably lower than h_1.

Our own criticism goes further as only the maximum flow principle in accordance with Boussinesq and Jameson can establish the correct flow equation. Furthermore, the coefficient C_d is only applicable to equation (16), while the contraction coefficient C_c can be used either in equations (11) or (17).

Nevertheless, it is surprising that the von Mises equation was not sufficiently recognised by earlier investigators. In comparison with the Weisbach or Bazin equations it has the great advantage of having the measured head term free of a velocity-of-approach correction, and the latter explicitly represented by a separate factor, see equation (17). These points appear to have escaped notice of those authorities, who established empirical discharge coefficient relations. Even Rehbock[21] who published, twelve years after von Mises, his 1929 weir equation in the same journal of the VDI, established a discharge coefficient which combined the influences of contraction, velocity-of-approach, and features of fluid properties, like surface tension.

Thus unified weir equations have been established which explicitly include terms related separately to velocity-of-approach and contraction influences. The latter term will be more extensively investigated in the following section (Part II). It is intended to show that the numerical values obtained by von Mises are corroborated by other investigators and should therefore be safely applied in the unified weir equations. These equations serve as a tool of investigation in analysing further influences related to special features of fluid dynamics, in particular properties like viscosity and surface tension.

PART II.—ON CONTRACTION COEFFICIENTS

The contraction coefficient established by von Mises[20] is the only reliable account directly related to weir flow problems, which the authors have been able to trace in a

Technical Contributors Section (*continued*)

fairly extensive search. In the previous Part I the authors have already shown why they could not make use of the discharge coefficient C_d as derived by von Mises. Nevertheless, the contraction coefficient C_c presented by von Mises in the first section of his series of articles was chosen as an essential term in the unified weir equations.

The phenomenon of contraction is due to the curved path described by the fluid particles in approaching the weir crest. Two features determine its numerical values, namely :

(*a*) the geometry of the boundary in the vicinity and upstream of the crest, and, more specifically, the angle formed by the weir plate with the water level surface beyond the point where the nappe shows no influence ;

(*b*) the area ratio, or approach velocity.

Few of the scientific, mainly mathematical, investigations have covered both problems sufficiently. The only recent account is due to H. W. Hahnemann.[9]

An investigation of both aspects is of interest as it gives a better insight into the results of some rather involved mathematics, which in case of conformal transformations often applied to determine the contraction coefficient may lack to the practical engineer the evidence afforded by simpler procedures. The first item also covers another problem hitherto neglected, namely the magnitude of error resulting from poor installation conditions due to a slightly inclined weir plate, or some changes in the approach geometry resulting from gravel or silt accumulating in front of the weir.

Progress in the derivation of unified weir equations was seriously handicapped by unsuccessful attempts in extending the relation of long structures to sharp-crested weirs. A contribution by E. Clarinval[2] may be mentioned as an interesting example of how to combine velocity-of-approach influences with contraction effects. He considered two sections of the fluid stream, one upstream of the weir where the water level h_1 above the weir crest is unaffected by the constriction, and the second section in plane with the weir plate, see Fig. 1(*a*). The head h_{crest} is determined by the distance of the water level above the weir crest. This, of course, means two measurements to determine the rate of flow, giving up the great advantage of a freely discharging weir, which requires only a single head measurement provided that a correct and complete flow equation is applied.

Clarinval uses the momentum theorem

$$\frac{1}{2}m(u_{crest}^2-u_1^2)=mg\frac{h_1-h_{crest}}{2} \quad . \quad (18)$$

From

$$u_1=u_{crest}\,h_{crest}/h_1 \quad . \quad . \quad (19)$$

we obtain

$$u_{crest}=C\sqrt{2g}h_1^{3/2} \quad . \quad (20)$$

where

$$C=\frac{\sqrt{1-h_{crest}/h_1}}{\sqrt{2(h_1^2-h_{crest}^2)}} \quad . \quad (20a)$$

From

$$Q=h_{crest}b_1u_{crest} \quad . \quad . \quad (21)$$

we obtain

$$Q=b_1\sqrt{2g}h_1^{3/2}h_{crest}C \quad . \quad (22)$$

or

$$Q=\frac{h_{crest}\sqrt{1-h_{crest}/h_1}}{\sqrt{2(h_1^2-h_{crest}^2)}}b_1\sqrt{2g}h_1^{3/2} \quad . \quad (23)$$

The first term on the right of this relation is of interest as it refers to the velocity-of-approach influence and implicitly to the contraction of the nappe. The contraction is partly but not completely included in h_{crest}. P. P. Boileau[2] has made some remarks on the complexity of this relation. He intended to publish further comments, but these were not accessible to the authors. However, it may be concluded from his observations[2] that the approximation of the Clarinval relation may become poor for large area ratios.

About forty years lapsed before considerable progress was achieved by the application of more stringent mathematical methods. Especially dealt with are the investigations by M. Réthy[22] (1894) and J. Hermanek[10] (1903). Réthy extended the Kirchhoff method[17] in applying conformal transformations. His investigations have a greater bearing on the actual weir problems as he introduced the concept of the " area ratio." Kirchhoff had only dealt with the limiting case of the contraction of a jet issuing from a slot situated in an infinite plane.

Réthy analysed irrotational, non-viscous flow issuing from infinity between two parallel walls. One of the walls was limited in its length by a rigid boundary perpendicular to this wall. Basic variables of the investigation were the total channel width $(h+w)$ and the length w of the vertically arranged boundary.

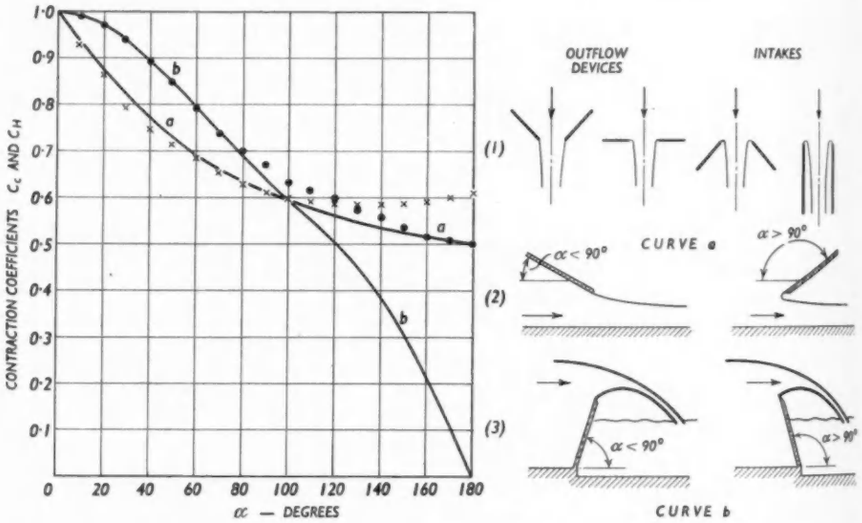

Fig. 2(*a*)—Variation of contraction coefficients with the angle of the boundaries in the vicinity of the aperture. Curve (*a*) H. W. Hahnemann, R. von Mises, and M. Réthy (" linear " contraction). Curve (*b*) " contraction" coefficient C_H of inclined weir plate, J. Hermanek. ●Truncated cones, J. Hermanek (" area " contraction). X Sluice, A. Koch. Fig. 2(*b*)—Schematic layout of devices investigated by various authorities. (1) H. W. Hahnemann, J. Hermanek, and R. von Mises. (2) Sluice, A. Koch. (3) Inclined weir, J. Hermanek

The length w of this boundary determines the width h of the aperture. Both variables may cover a complete range of area ratios $h/(h+w)$.

The first Part of Réthy's investigation was concerned with one of the walls having unlimited dimensions. However, Réthy dealt with another case in which this wall was omitted and replaced by the axis of symmetry representing the flow between two parallel walls with perpendicular boundaries forming a symmetrically arranged opening from which the contracted fluid jet issued. Again the limiting case of a channel of infinite width, i.e. flow from a slot arranged in an infinite plane resulted in the Kirchhoff term,[17] namely $\pi/(2+\pi)$.

Réthy presented two relations for the contraction coefficient, which include an auxiliary angle $(1-1/k)^{\frac{1}{2}}$ wherein k is defined by the following limits $1 \leqslant k \leqslant \infty$.

The area ratio is given by

$$\frac{h}{h+w}=\left[1+\frac{2\sin^{-1}(1-1/k^2)^{\frac{1}{2}}}{\pi(k^2-1)^{\frac{1}{2}}}\right]:\left[\frac{k+1}{k-1}\right]^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (24)$$

Corresponding values of the contraction coefficient are obtained by inserting the same values of k into the following relation

$$C_c=1:\left[1+\frac{2\sin^{-1}(1-1/k^2)^{\frac{1}{2}}}{\pi(k^2-1)^{\frac{1}{2}}}\right] \quad . \quad (25)$$

This means that a certain value of the auxiliary term k relates a specific area ratio to each value of the contraction coefficient.

Relations of similar design have been introduced by R. von Mises (1917) and by N. E. Zhukovskii (1936) (in accordance with H. W. Hahnemann[9]).

Area ratio :

$$\frac{h}{h+w}=\left(1+2\frac{2\vartheta}{\pi\tan 2\vartheta}\right)\tan\vartheta \quad . \quad (26)$$

Contraction coefficient :

$$C_c=\frac{\pi}{\pi+2\dfrac{2\vartheta}{\tan 2\vartheta}} \quad . \quad . \quad . \quad (27)$$

Again ϑ is an auxiliary angle which correlates a specific value of the contraction coefficient with a corresponding area ratio. These relations are similar to those established by von Mises. An example of the method of deriving the contraction coefficient by means of elementary mathematical procedures due to A. Koch[15] is given in the Appendix.

Several curves in Fig. 2(*a*) illustrate the influence of geometry and design of the structure on the contraction coefficient. In Fig. 2(*b*) the geometrical design of the devices investigated by various authorities is schematically shown. The trend of the curves may reflect some shortcomings of one or the other mathematical procedures in establishing the contraction coefficient. With reference to

curve *a* it should be noted that the numerical values given by von Mises, Réthy and Hahnemann are identical in spite of slight differences in the method of obtaining the results. The close agreement of the results of the investigation by A. Koch is remarkable (see Appendix): he established the contraction coefficient of a water jet issuing from a sluice. As already mentioned he obtained his values by means of a simple mathematical procedure applying the momentum theorem. Nevertheless, his results in the range of angles between 90 deg. and 180 deg. should be taken with caution.

J. Hermanek[10] applied the theorem of momentum to derive the contraction coefficient. His assumptions differ from flow conditions used in connection with the previously mentioned method of conformal transformations. His investigations are also covered by the complete range of angles between 0 deg. and 180 deg. for flow through truncated cones, see Fig. 2(*a*). The layout is comparable to the upper row of diagrams in Fig. 2(*b*). In view of the different method of establishing contraction effects and also a different interpretation of the contraction coefficient‡ the discrepancy between his results and those of von Mises is understandable. It should be noticed that his investigation refers also to zero approach velocity.

The following Table II compares effects of

TABLE II—*Multipliers related to Contraction Coefficients Varying with Area Ratios and Width Ratios Respectively*

Area ratios for column (ii) Width ratios for columns (iii) and (iv) (i)	Multipliers obtained from contraction coefficients		
	J. Hermanek § related to area ratios (ii)	related to width ratios (iii)	R. von Mises related to width ratios (iv)
0	1·0	1·0	1·0
0·1	1·018	1·002	1·002
0·2	1·039	1·006	1·008
0·3	1·065	1·016	1·018
0·4	1·094	1·028	1·033
0·5	1·130	1·051	1·054
0·6	1·173	1·083	1·083
0·7	1·226	1·126	1·124
0·8	1·293	1·194	1·182
0·9	1·372	1·297	1·278
1·0	1·50	1·50	1·637

the velocity-of-approach factor on the contraction coefficient obtained by Hermanek with those by von Mises (Table I, column (vii) divided by 0·611). The trend of the test points in Fig. 2(*a*) and Hermanek's basic coefficient of 0·6667 for 90 deg. explains some of the differences occurring in Table II. It should be noted that usually the basic contraction coefficient is 0·611.

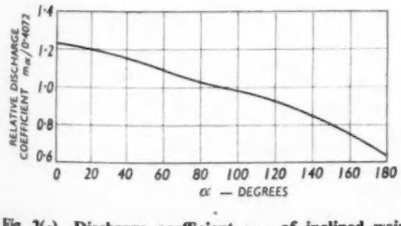

Fig. 2(*c*)—Discharge coefficient m_α of inclined weir plates related to the basic coefficient of a vertical plate 90 deg. =0·4072; for definition of angle α, see Fig. 2(*b*) (3)

In Fig. 2(*c*) we have plotted, for inclined weir plates, the ratio of Hermanek's weir coefficients to his basic discharge coefficient m=0·4074. The coefficients are defined by the following flow equation

$$Q=m_\alpha b\sqrt{2g}h^{3/2} \quad . \quad . \quad . \quad (28)$$

where

$$m_\alpha=\tfrac{2}{3}(1+C_H) \quad . \quad . \quad . \quad (28a)$$

C_H is the "contraction" coefficient plotted in Fig. 2(*a*), curve *b*. For its full understanding the original paper[10] should be consulted. Here we are only concerned to demonstrate the diversity of the "contraction" coefficients.

From the practical point of view the ratio $m_\alpha/0{\cdot}4072$ illustrated in Fig. 2(*c*) gives a better insight into the influence of an inclined weir plate on contraction effects. It should be noted that these values are somewhat restricted as they refer only to zero approach velocity, i.e. a very large height of the crest of the weir over the channel bottom related to small heads *h*.

PART III—ON DISCHARGE COEFFICIENTS

In the first paragraph of this article reference was made to the policy adopted in fluid flow measurements in closed conduits. A common type of flow equation for all pressure difference devices is used which also defines appropriate discharge coefficients.

Systematic investigations to establish comparable discharge coefficients for weir flow had never been attempted. Most of the published results on measuring weirs are unsuitable to further analysis. Comprehensive discharge coefficients were introduced mainly based on empirical equations which combined all possible influencing factors without sufficient discrimination.

In contrast, the discharge coefficients *C* which the authors[6, 7] recommend are comparable to those in closed conduits. The theoretical equations as outlined in Part I serve as a tool to analyse discharge coefficient characteristics. It should be noted, that *C* differs from C_d applied in the von Mises equation (16) as the latter includes both the contraction coefficient and the velocity-of-approach factor. The equations which define *C* are

Sharp-crested weirs :

$$Q=(2/3)^{3/2}C[C_{va}C_c\sqrt{3}]b_1\sqrt{g}h_1^{3/2} \quad . \quad (29)$$

Venturi weirs :

$$Q=(2/3)^{3/2}C\,C_{va}b_2\sqrt{g}\,h_1^{3/2} \quad . \quad . \quad . \quad (30)$$

Previously, the authors drew attention[6, 7] to some misconceptions regarding the meaning of discharge coefficients. Some authorities try to establish a "linear" relation of the discharge coefficient by introducing "correcting" terms into one or more of the basic variables. A well-known example is the Rehbock equation in which a constant head value is added to the measured head over the weir crest. These and similar procedures tend to mislead the limit of applicability of the flow equation. Our aim is to specify conditions when deviations of the discharge coefficient from its normal characteristic become pronounced and the limits of "constancy" have been reached. Other authorities try to establish a discharge coefficient of unity which can be achieved only by introducing corrections to other terms in the flow equation. While one term by such artifices may become nearly constant the other term which otherwise could have been easily evaluated becomes rather unwieldy. The apparent gain in one of the terms is lost by corrections on an otherwise straightforward relation.

Even under normal conditions, which include variations of the physical properties of the liquid to be measured and also some particular features of fluid dynamics including separation and boundary layer effects, an empirical discharge coefficient has to be introduced. In our present state of knowledge of the turbulence problem it would be impracticable from the engineer's point of view to elaborate the basic theoretical flow equations by introducing further terms which could replace the discharge coefficient. The original physical significance of the basic relations which were employed for the derivation of the flow equations through constricted channels should be preserved. The basic principles concerned are the law of conservation of energy, represented by the Bernoulli theorem, Newton's second law, the maximum flow principle or the problem of Boussinesq. The Bernoulli theorem should not be misrepresented by the introduction of random terms related to frictional "losses," viscosity, or other factors, otherwise the results may apply only to specific cases.

The basic relations have provided the velocity-of-approach factor and its numerical values. The same relation cannot establish the coefficient of contraction, which is a specific physical phenomenon. It can be derived by special mathematical methods, as demonstrated by von Mises. Empirical discharge coefficients are required as dissipation of energy occurs. Flow through contractions is related to several irreversible phenomena, e.g. frictional losses, separation of boundary layers, and viscosity and surface tension.

The empirical discharge coefficients as defined by equations (29) and (30) should be analysed on the basis of non-dimensional groups of dynamics. These groups will reveal certain ranges of flow conditions over which one or the other irreversible phenomena has a predominant influence. Primarily these groups serve to establish limits of "constancy," but, the methods of dimensional analysis can lead to ambiguous results. First of all it must be clearly understood that they can never disclose factors which the individual experimenter did not know or overlooked when starting his problem. A further drawback of the use of dimensional analysis is that it cannot reveal numerical values, like the contraction coefficient or the velocity-of-approach factor. These limitations should be recognised otherwise serious errors may be introduced into the flow equations.

With reference to the application of non-dimensional groups as tools in representing discharge coefficient characteristics three views should be analysed more carefully, namely :

(1) a formal approach in establishing non-dimensional terms by means of dimensional analysis,

(2) some relations obtained by means of curve-fitting procedures, expressing the discharge coefficient as a function of modified Reynolds and Weber numbers,

(3) establishing the discharge coefficient on the basis of an "area ratio" concept, which in turn is related to the Froude number as a major criterion, with superimposed Weber number and/or Reynolds number influences over selected ranges.

Dimensional analysis, may present the various non-dimensional terms somewhat obscurely. The various terms appear to be on equal status, the set of terms may be incomplete or over-determined, or may include terms which are doubtful as they have no physical significance.

The discharge coefficient as a function of several non-dimensional terms may be more

‡ Hermanek defines the contraction coefficient by the area ratio, both of the contracted jet and the aperture. R. von Mises and M. Réthy introduced "linear" contraction coefficients.

§ Hermanek in his paper on page 896 presented only the "area ratio" concept, which is given in column (ii). The linear contraction values of column (iii) have been determined from column (ii).

Technical Contributors Section (*continued*)

generally written

$$C=\left[\frac{b}{h}, \frac{\mu b}{Q\rho}, \frac{h^3\sigma}{Q^2\rho}, \frac{h_1 b_2}{(h_1+w)b_1}, \frac{w}{h}\right] \quad . \quad (31)$$

This expression does not explicitly refer to the Froude number which, however, may be related to the following term

$$\frac{h_1 b_2}{(h_1+w)b_1} \quad . \quad . \quad . \quad . \quad (32)$$

For sharp-crested weirs the second term on the right of relation (31) becomes

$$h_1/(h_1+w) \quad . \quad . \quad . \quad (32a)$$

but this expression is related to the last term w/h as

$$\frac{w}{h}=\frac{1-h/(h+w)}{h/(h+w)} \quad . \quad . \quad . \quad (33)$$

Therefore, in a complete set the last term may become redundant. Nevertheless, the relation (31) suggested by N. O. Boughton[6] in a written communication gives a comprehensive illustration of predominant terms characterising the discharge coefficient.

Regarding the " genuine " non-dimensional groups of dynamics[8], opinions differ considerably. Some authorities state that it must not be supposed that non-dimensional quantities are unique, on the contrary, there is an immense choice, for any product combination of the non-dimensional quantities, which results in other non-dimensional terms. They elaborate this statement by referring to Reynolds and Froude numbers. They present as an example of infinite variety of possible ways of writing both numbers the following terms

$$\frac{u^2}{vg} \text{ or } \frac{g\,l^3}{v^2} \quad . \quad . \quad . \quad . \quad (34)$$

The latter term is also known as the Galileo number which gives the Grashof number after expanding by a non-dimensional potential or driving force.

In the opinion of the same authorities there exists an immense variety of mathematically equivalent expressions to choose from. The choice should be mainly governed by convenience. However, as a rule it is thought convenient to use the Reynolds number and the Froude number rather than other combinations. Nevertheless, and in contradiction to this recommendation a modified Reynolds number

$$\frac{g^{\frac{1}{2}}\,l^{3/2}}{v} \quad . \quad . \quad . \quad . \quad (34a)$$

was introduced in the general weir equation and also in the Francis weir equation. This modified Reynolds number is expressed as a combination of the Reynolds and Froude numbers and is the square root of the Galileo number.

Langhaar[18] has clearly stated that the combination of two-non-dimensional groups does not establish a new group. The authors endorse his view. Combinations of two genuine non-dimensional groups by means of multiplication or other elementary mathematical operations are not permissible.[8] Each group must be applied individually. The groups form entities and an exhaustive proof is required if any modifications or expansions of non-dimensional groups and their components are intended.

The representation of weir discharge coefficients by Reynolds and Weber numbers is chosen by the authors as an example to demonstrate some ambiguities resulting from a faulty application of those groups. In a paper on flow over sharp-edged weirs A. H. Jameson[14] related the discharge coefficient to Reynolds and Weber numbers. His idea on this subject are summarised in the following two quotations‖ :

" All fluid motion involves the Reynolds number R_e, but where a liquid is in contact with air, the Weber number W_e may also play a part. In addition, a weir has the linear quantities h, b, w, and t or rather, the ratios h/b, h/w, and h/t. The ratio h/b may be ignored if it is small and the side-walls are reasonably smooth and the problem then becomes two-dimensional.

" It seemed possible, in the case of weirs, that h/w might be combined with R_e and h/t with W_e ; and it was, in fact, found that the coefficient C was a function of the two non-dimensional quantities

$$(R_e)=R_e\left(\frac{h}{w}\right)^8 \text{ and } (W_e)=W_e\left(\frac{h}{t}\right)^3$$

Curves of log C for convenient values of log (R_e) were therefore plotted on a base of log (W_e), as shown in Fig. 3. These the author calls ' contours ' of log (R_e) by analogy with contours of altitude on a map."

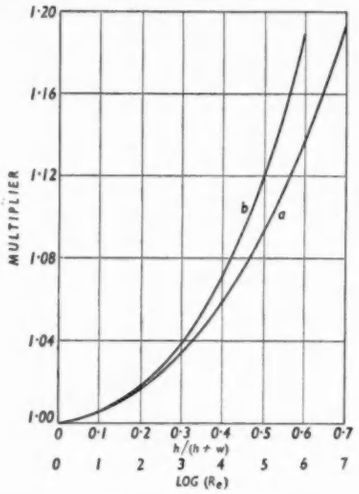

Fig. 3—Comparison of a multiplier, curve *a*, obtained from the Jameson discharge coefficient, equation (35), with a multiplier, curve *b*, related to the velocity-of-approach

Jameson established a relation for the discharge coefficient C_o at a very large modified Weber number, namely log (W_e)= 11·6. For this value surface tension effects may become negligible. His final formula (on page 55, at the end of his paper) for (R_e) >1 is :

$$C_o=0{\cdot}4178+0{\cdot}000\,448\,(\log(R_e)+1)^{2.5} \quad (35)$$

In Fig. 3 the authors have plotted on the basis of (R_e) a multiplier obtained from the Jameson relation in dividing C_o by 0·4178. Equation (35) as well as curve (*a*) could convey the impression that a considerable Reynolds number influence exists with notable increases in the range of large Reynolds numbers. In Fig. 3 there are two abscissa scales, namely :

(*a*) log (R_e)

(*b*) $h/(h+w)$

In the same diagram a curve (*b*) is shown which represents a multiplier based on the authors' unified weir equation. This multiplier correlates the area ratio $h/(h+w)$ with the combined coefficients $C_{va}\ C_e\ \sqrt{3}$, a relation which is influenced by the velocity-of-approach. It is obtained from Table I dividing the values of column (x) by 1·058.

With an increasing velocity-of-approach which also results in large area ratios, the Reynolds number will become larger. It would be wrong to say that in the range of small Reynolds numbers the discharge coefficient is nearly independent of this non-dimensional group and to conclude that with increasing Reynolds numbers the considerable change in the discharge coefficient could be attributed to Reynolds number influences. Such conclusions have no physical significance and would be meaningless. The trend of curve (*b*) clearly shows that the variation of C_o, represented in Fig. 3 by a multiplier, should be attributed mainly to the velocity-of-approach. This representation clearly demonstrates the advantage of separating the contraction coefficient as well as the velocity-of-approach factor from the empirical discharge coefficient C. The latter may show pronounced Reynolds and Weber number

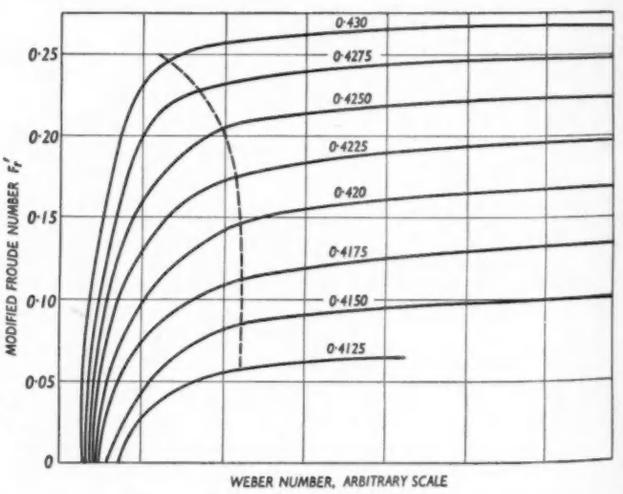

Fig. 4—Eisner diagram with modified Froude number, equation (39), and Weber number as co-ordinates. Set of curves with discharge coefficient *C'*, equation (40), as parameter

‖ In the quotations R_e and W_e is used instead of R and W applied by Jameson in the original text. The weir height p of the original has been replaced by w used throughout the present article.

influences over certain ranges as shown in Fig. 4.

Jameson has applied modified Reynolds and Weber numbers. Such modifications or expansions of genuine non-dimensional groups of dynamics may only be permissible by indicating the limits of such procedures. Most of the elementary mathematical operations become meaningless when applied to "genuine" non-dimensional groups of dynamics, as recently shown by one of the authors.[8] By way of example we may consider the modified Reynolds number introduced by Jameson

$$(R_e)=R_e\,(h/w)^6 \quad . \quad . \quad . \quad (36)$$

Over a useful range of area ratios, say from 0·05 to 0·7, the term h/w lies approximately within the limits of 0·06 and 2·33. The sixth power of h/w varies over this range in the ratio of 1 to 4000 million. If the (R_e)-term is not qualified, considerable confusions may result from such modifications. Assuming an area ratio of 0·7 the term $h/w=2·33$ in its sixth power is approximately 150. Assuming a large $\log(R_e)=7$ would result in a Reynolds number of approximately 70,000 which is for a large area ratio rather a low value. In case of flow through pipe orifices the constancy limit would not yet have been reached for a Reynolds number of 70,000. Taking another extreme, say $h/w=0·1$, which gives

$$(h/w)^6=0·000\,001$$

for $\log(R_e)=1$ the Reynolds number would be 10,000,000. These extreme values contradict one the other, as for small area ratios comparatively low Reynolds numbers, say of the order of 100,000, are likely. For large area ratios the Reynolds number may exceed 1,000,000. In the Jameson relation (35) the Reynolds number is proportional to $h^{3/2}$ which correlates the Reynolds number with the area ratio and in turn with h/w. With these examples the intention of the authors is merely directed to warn against the application of so-called "modified" non-dimensional groups without discrimination.

The main results of Eisner's work (1933) is a relation between the Froude number and the area ratio, including some minor influences of Reynolds and Weber numbers at least over a considerable measuring range, where a high degree of accuracy is required. However, in studying Eisner's monograph[3] care should be taken to avoid confusion as he bases his modified non-dimensional groups on two initially differing relations.

F. Eisner in pursuing the von Mises weir flow equations (13) to (16) introduced modified area ratios, velocities, Froude, Reynolds, and Weber numbers. He also defined a theoretical discharge coefficient on the basis of those modified quantities. But, in his re-assessment of the weir flow equations by Rehbock the initial flow equation applied by Eisner differs from the von Mises equations.

Eisner introduced the total energy head in the upstream channel as a reference value which defines all crucial variables, namely :

$$h'=h+\frac{u^2}{2g} \quad . \quad . \quad . \quad . \quad (37)$$

This term defines a modified upstream mean velocity

$$u'=\frac{Q/b}{h'+w} \quad . \quad . \quad . \quad (38)$$

Accordingly the Froude number is written

$$F_r'=\frac{u'}{\sqrt{gh'}}=\frac{Q/b}{(h'+w)\sqrt{gh'}}=C'\sqrt{2}\frac{h'}{h'+w} \quad (39)$$

The right-hand term of equation (39) is obtained from the basic weir equation

$$Q/b=C'\sqrt{2g}h'^{3/2} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

These relations were applied by Eisner when evaluating the Rehbock (1913) weir equation. The discharge coefficient C' should not be confused with the theoretical discharge coefficient C_d based on the von Mises equations, which were dealt with in an earlier part of Eisner's investigations. As von Mises applied the Weisbach equation when establishing the discharge coefficient C_d two different sets of numerical values for the discharge coefficients will be obtained as both the basic equations (10) or (16) and (40) differ in the terms related to the head over the weir crest as can be seen from the following terms :

Weisbach/von Mises

$$\left[\left(h_1+\frac{u^2}{2g}\right)^{3/2}-\left(\frac{u^2}{2g}\right)^{3/2}\right] \text{ or } [(1+z^2)^{3/2}-z^3)]$$

Eisner

$$\left(h_1+\frac{u^2}{2g}\right)^{3/2}$$

Fig. 4 represents the discharge coefficient C' as a parameter of a set of curves with F_r' as the ordinate and W_e as the abscissa based on the Rehbock equation. The Weber number scale is only an arbitrary one. In the range of low Reynolds numbers this scale may also include a superimposed Reynolds number influence. From the practical point of view and also for future work connected with improving flow measurement accuracy this representation is of importance. A limiting curve, indicated by a dotted line, is shown separating the range on its right-hand side over which the discharge coefficient may be considered to be constant within specified tolerances, say plus or minus 1 per cent. The limit of constancy should be defined by certain values of Weber and/or Reynolds numbers for various area ratios. Investigations on those outlines could bring the sharp-crested weir as an accurate measuring device well in line with the primary pressure difference devices in closed conduits, as adopted by many National Standards Institutions.

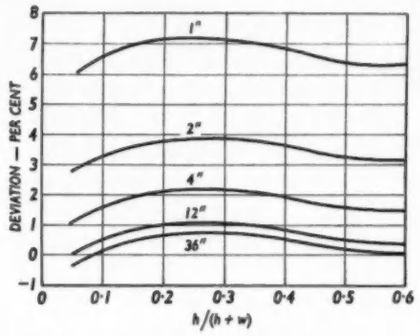

Fig. 6—Deviations in per cent from discharge coefficient $C=1$, equation (29), related to the depth ratio. Set of curves with the head h as parameter

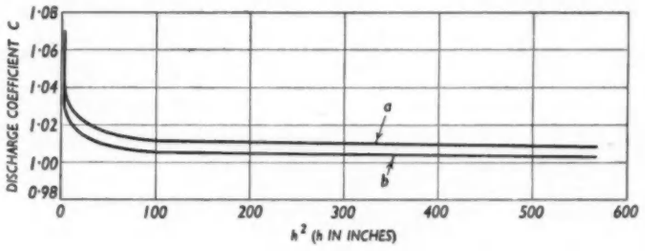

Fig. 5—Discharge coefficient C, equation (29), with abscissa values related to the square of the head over the weir crest. Curve (a) $h/(h+w)=0·3$. Curve (b) $h/(h+w)=0·6$

The authors propose a further step. It is to use the unified weir equations to establish the discharge coefficient characteristics and to analyse the discharge coefficient C, defined by equations (29) and (30) on the basis of relevant genuine non-dimensional groups.

Assuming that the empirical weir equations by Rehbock which were established by means of a curve fitting procedure, exactly represent extensive experimental results, we may apply his equation in a re-assessment of discharge coefficient characteristics. The Rehbock discharge coefficient will be used to establish at least the trend of combined Weber and Reynolds number influences.

In Fig. 5 the abscissa is proportional to h^2, which in turn is proportional to the Weber number. The Reynolds number scale should be proportional to $h^{3/2}$, which may be considered to be approximately in line with the Weber number scale. Therefore, the curves (*a*) and (*b*) for two area ratios indicate the general trend of Weber and Reynolds number influences. The steep rise of the discharge coefficient at the lower end of the scale should be noted. Accepting certain tolerances some limiting Weber or Reynolds numbers could be specified below which the numerical values of the discharge coefficient should not be used. These limits may also be characterised by a minimum area ratio or in accordance with present-day practice by a minimum head value ; possibly these various factors are interrelated. Concluding the remarks on Fig. 5, the fact that the discharge coefficient is close to unity should not be over-emphasised. The closeness to unity says only that both the coefficients C_e and C_{va} cover all essential features besides the other terms in the unified weir equations (11) and (12) or (29) and (30) respectively.

Fig. 6 shows at a large scale the deviations occurring at low heads corresponding to small numerical values of Weber and Reynolds number influences. There is only a small change in the discharge coefficient over a considerable range of area ratios with the head over the crest of the weir as parameter. The particular shape of the curves may be due to the design of the Rehbock discharge coefficient relation and its deviation from the basic terms applied by the authors in their unified weir equation. Nevertheless, these curves in both diagrams show the advantage of using the weir equations presented by the authors as tools for investigating discharge coefficient characteristics.

Concluding our investigation on discharge coefficients, it should be noted that C for Venturi weirs defined by equation (30) differs from various coefficients presented in previous publications by one of the authors[4, 5].

APPENDIX

Elementary Derivation of the Contraction Coefficient

The phenomenon of "contraction" is of great interest to the designer. Its application is not restricted to flow measurement but covers a wide range of flow devices dealing

Technical Contributors Section (*continued*)

with flow in either direction. Early attempts were made by J. Hermanek[10] (1903) and A. Koch[15] (1926) to derive the contraction coefficient by simpler and to the practical engineer more comprehensible mathematical methods than conformal transformations. An assessment of the latter method is due to F. Kötter.[16] A short account of the method introduced by A. Koch is presented by C. Jaeger in his *Engineering Fluid Mechanics*.[12]

A. Koch reduced the momentum theorem from a dynamic to a static problem which comprises only a set of balancing forces. In Fig. 7 the fluid approaches the opening *BE* of a sluice radially from all directions. The velocity u_1 in the approach channel can be assumed to be constant before the fluid reaches the cylindrical surface *LM*. Its circumference is equal to the depth h_1 of the water stream. Beyond the surface *LM* the fluid particles are accelerated while flowing radially towards the cylindrical surface *AB*, the radius of which is equal to the opening $BE=a$ of the sluice.

In the zone *ABE* exists an equilibrium of several forces. The forces directed to the centre *E* of the cylindrical surface producing the acceleration of the fluid particles, and the force due to the weight of the fluid of the cylindrical quadrant *ABE* are counteracted by a force which is proportional to the total head and to the area of the quadrant projected on the bottom of the channel. The last two forces cause the fluid particles to flow parallel to the bottom of the channel.

The resultant force *K* of the first mentioned forces acting upon the quadrant *AB* is obtained from the force elements *dK* acting upon a surface element $ad\phi$ of the quadrant *AB*

$$dK=ad\phi\,(H-a\sin\phi) \quad . \quad . \quad (41)$$

where *H* is the total head

$$H=h_1+u_1^2/2g \quad . \quad . \quad . \quad . \quad (41a)$$

Integrating (41) between the limits $\phi=0$ to $\phi=\frac{\pi}{2}$, we obtain

$$K=a\left(\frac{\pi}{2}H-a\right) \quad . \quad . \quad . \quad . \quad (42)$$

In some of the relations it is assumed that the forces are proportional to the areas stated. This has been done to simplify the equations and does not in any way invalidate the argument.

The other forces are :

(*a*) the weight of the fluid contained in the quadrant *ABE*

$$G=\frac{\pi}{4}a^2 \quad . \quad . \quad . \quad . \quad . \quad (43a)$$

(*b*) the force acting on the projection of the quandrant *AB* onto the channel bottom, which as a reaction force is directed upwards

$$F=aH_1 \quad . \quad . \quad . \quad . \quad . \quad (43b)$$

(*c*) the pressure on the opening *BE* of the sluice, which is initially supposed to be closed. Fig. 7 shows the component forces H_1-a and H_1 which co-act and which give

$$W=a\frac{(H_1-a)+H_1}{2}=\frac{a}{2}(2H_1-a)$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (43c)$$

If the passage *BE* of the sluice, which initially was assumed to be closed, is open the force elements *dK* act radially and the forces $(F-G)$ deflect the fluid particles towards the opening *BE*.

The main force *W* (see insert, Fig. 7) may be sub-divided into two forces *Z* and *D* assuming that the path of the particles passing the sluice related to the lower layer which is characterised by the force *D* is already parallel to the bottom of the channel. It is thus

$$W=Z+D \quad . \quad . \quad . \quad . \quad . \quad (44)$$

The force *Z* is balanced by the centrifugal forces of the contracting stream, see insert, Fig. 7. *D* is balanced by the contracted fluid stream where

$$h_2=C_c a \quad . \quad . \quad . \quad . \quad . \quad (45)$$

C_c being the contraction coefficient.

For *D* we obtain a similar expression as for *W*, namely :

$$D=\frac{h_2}{2}(2H_1-h_2) \quad . \quad . \quad . \quad (46)$$

Koch assumes the driving forces *K* and *D* to be proportional to the corresponding deflecting forces $(F-G)$ and $Z=W-D$, namely :

$$K/(F-G)=D/(W-D) \quad . \quad . \quad . \quad (47)$$

from which we obtain

$$D=\frac{K}{K+F-G}W \quad . \quad . \quad . \quad (48)$$

Substituting in equation (48) all the terms for *D*, *F*, *G*, and *K*, equations (42) to (46), re-arranging and introducing $n=H_1/a$ we obtain finally the relation for the contraction coefficient

$$C_c=\frac{h_2}{a}=\frac{\left(\frac{\pi}{2}-\frac{1}{n}\right)\left(2-\frac{1}{n}\right)}{\left(2-\frac{C_c}{n}\right)\left[\left(\frac{\pi}{2}+1\right)-\frac{\frac{\pi}{4}+1}{n}\right]} \quad (49)$$

For very large ratios H_1/a the term $1/n$ approaches zero. We obtain the contraction coefficient as derived by Kirchhoff

$$C_c=\frac{\frac{\pi}{2}2}{2\left(\frac{\pi}{2}+1\right)}=\frac{\pi}{\pi+2} \quad . \quad . \quad . \quad (49a)$$

So far a wall vertical to the bottom of the channel has been considered. Koch also established a relation for the contraction coefficient when the wall is at an angle to the bottom of the channel for a range of angles from 0 deg. to 180 deg. Again for large ratios H_1/a he obtained the contraction coefficient

$$C_c=\frac{\alpha}{1+\alpha-\cos\alpha} \quad . \quad . \quad . \quad (50)$$

Values corresponding to this relation for the complete range from 0 deg. to 180 deg. were plotted in the diagram, Fig. 2(*a*), which also includes curves by other investigators illustrating the influence of the geometry of the design, as given in Fig. 2(*b*).

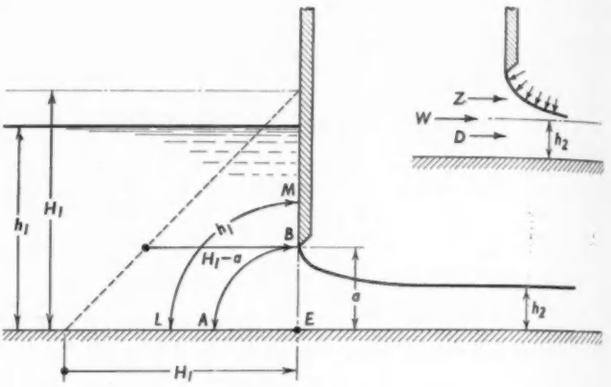

Fig. 7—Scheme of balancing forces related to the flow through a sluice, A. Koch

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Transient Flow of Gas in a Pipe of Variable Area

By M. H. NASSIF, B.Sc., Ph.D., A.M.I.Mech.E.*

The energy acquired by a wave of finite amplitude can be utilised more efficiently and with better flexibility when the wave is being propagated through a properly designed pipe of variable area rather than if the wave is reflected at an open end of a pipe of parallel section. The method suggested in the following analysis is concerned with calculations of non-steady flow through pipes of variable area containing uniform or non-uniform gas under isentropic conditions of flow. This method, while providing the greatest possible accuracy, avoids the extremely tedious and involved techniques associated with other investigations. The treatment given is based on a consideration of transient flow phenomena being composed of two oppositely moving disturbances superimposed on each other, a method of aproach which has been fruitfully applied in other fields of analogous nature. These disturbances together with other boundary conditions constitute the variables which can be conveniently arranged in chart form. There is also reason to believe that a similar representation may be obtained in case other influences disregarded in the present analysis were valid.

WAVE action through pipes of variable area is encountered in many applications. The inherent gas may be non-uniform, being composed of several layers of gas of different nature and unequal levels of entropy. Different methods of approach have been applied to deal with problems of such character. These methods mainly are :

(A)—The Method of Characteristics.—This constitutes a semi-graphical solution based on the so-called characteristic equations.[1] The assumptions involved are rigorous and the results of calculations by this method give the closest agreement with experimental records. This method is unfortunately extremely laborious and time consuming.

(B)—Approximate Analytical Solution Derived from the Characteristic Equations.—The characteristic equations for a pipe of variable area cannot yield, as they stand, any form of general solution. It is possible however, by adopting certain simplifying assumptions, to integrate these equations and the solutions obtained, amended by some correction factors, can be represented in chart form.[2] This method is nevertheless much less accurate than the previous treatment and is in addition subject to certain restrictions. The method applies essentially for straight conical pipes (diffusers); the gas within should be of the same nature throughout and should be free from temperature discontinuities. Owing to the large number of variables involved each set of the derived charts can only serve for a diffuser of fixed proportions in conjunction with one wave configuration. The flow parameters at one end of the diffuser can be determined from the charts when the parameters at the other end are known, yet no information regarding the value of these parameters at intermediate positions in the diffuser nor dealing with phasing can possibly be obtained.

(C)—The Small Wave Theory.—In this treatment the particle velocity is considered negligibly small in relation to the acoustic velocity.[3] The method is apparently unsuitable for applications associated with high particle velocities.

Present Treatment

Comparison of the three methods outlined has shown[2] that method *(A)* is quantitatively the most reliable. The present treatment was planned to give the same degree of accuracy as method *(A)* while cutting down to a great extent the amount of labour involved. Consequently the same basic assumptions adopted in method *(A)* were applied, namely that the flow is one-dimensional, that no separation occurs between the gas and pipe walls and that diffusion effects are eliminated across the surface of separation between two different adjacent gas layers. The dependent flow parameters for a particular pipe enlargement are computed by method *(A)* through a process of successive approximation. These parameters can be obtained directly by the method proposed from analytical solutions which correlate the dependent and independent flow parameters in a manner most convenient for chart (or nomographic) representation.

General Considerations

Partial reflection occurs when a single wave (or alternatively two oppositely moving waves) undergoes a change of pipe area or crosses a surface of separation between two different gas layers. A single wave travelling down a pipe of variable area or through non-uniform gas sends back eventually a train of reflected waves moving in opposite direction to the main incident wave. The problem becomes rather complex with irregular wave profiles, but is largely simplified when the following methods are applied (Fig. 1) :

(1) A pipe of variable area is considered as a succession of parallel pipe enlargements.

(2) A wave of irregular shape is treated as a train of regular isentropic flat-topped waves.

The problem under consideration involves evidently three basic problems, namely :

(I) The crossing through uniform gas of two regular oppositely moving waves at a pipe enlargement. This is given in the first part of the present analysis.

(II) The crossing of two regular oppositely moving waves at the surface of separation between two different gas layers. This is analysed in the second part of the treatment.

(III) The phasing of the different crossing processes taking place at intermediate sections of the pipe. This can be determined by applying methods similar to those used to solve the process of superimposition of two oppositely moving waves in a parallel pipe.[4]

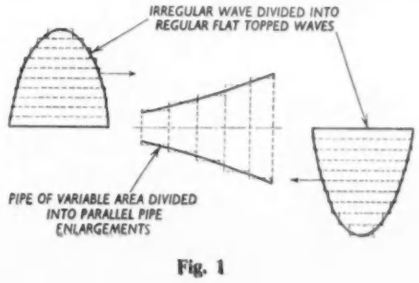

Fig. 1

Theoretical Analysis

In the present analysis use is made of the fundamental equations of non-steady flow.[5] These fundamental equations of frictionless,

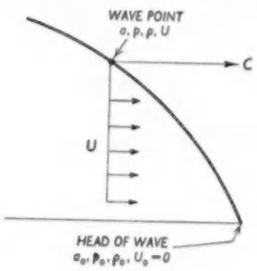

Fig. 2

isentropic, one-dimensional, transient flow may be summarised as follows :

(i) *Single Waves.*—The particle velocity for a wave point of pressure p is given by Fig. 2 :

$$U=\frac{2}{K-1}(a-a_o)=\frac{2}{K-1}a_o\left[\left(\frac{p}{p_o}\right)^{\frac{K-1}{2K}}-1\right]$$

$$=\frac{2}{K-1}a_o(x-1) \qquad \ldots\ldots (1)$$

Where : a=acoustic velocity at the point considered.

Notice may be given to the fact that in the present analysis the pressure ratio x is referred to as the wave amplitude.

The velocity of propagation of the wave point under consideration

$$\vec{C}=\vec{U}+a\times a_o\left(\frac{K+1}{K-1}x-\frac{2}{K-1}\right) \ldots (2)$$

(ii) *Superimposition of Waves.*—A rightward moving wave AA of amplitude

$$x_i=(p_i/p_o)^{\frac{K-1}{2K}}$$

and a leftward moving wave BB of amplitude

$$x_r=(p_r/p_o)^{\frac{K-1}{2K}}$$

are propagated through uniform gas in a parallel pipe (Fig. 3). When the two waves are superimposed the resultant particle velocity :

$$\vec{U_T}=U_i+U_r=\frac{2}{K-1}a_o(x_i-x_r) \quad . (3)$$

Notation

a—Acoustic velocity.
A—Pipe area.
C—Velocity of propagation.
K—Isentropic index.
p—Pressure (absolute).
s—Distance.
t—Time.
U—Particle velocity $\frac{K-1}{2K}$
x—Pressure ratio (p/p_o)
$\alpha, \beta, \gamma, \delta, \phi$ – Constants.

Suffixes

o—Refers to undisturbed conditions in pipe.
i—Refers to rightward moving waves (such waves are also referred to as incident waves).
r—Refers to leftward moving waves (these waves may also be termed as reflected waves).
T—Refers to superimposition conditions.
R—Refers to pipe portion to right of pipe enlargement or surface of separation.
L—Refers to pipe portion to left of enlargement or surface of separation.

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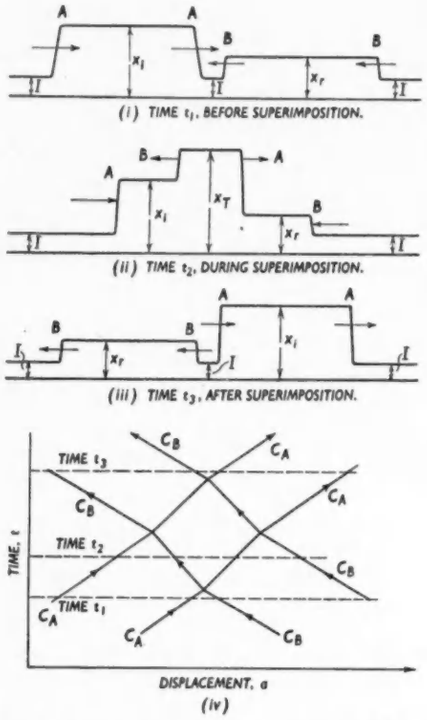

Fig. 3—The superimposition of waves of finite amplitude

and the resultant pressure p_T is given by :

$$(p_T/p_o)^{\frac{K-1}{2K}} = x_T = x_i + x_r - 1 \quad . \quad . \quad (4)$$

The velocity of propagation of AA during superimposition :

$$\overrightarrow{C_A} = a_o\left(\frac{K+1}{K-1}x_i + \frac{K-3}{K-1}x_r - 1\right) \quad . \quad (5)$$

and the velocity of propagation of BB during superimposition :

$$\overleftarrow{C_B} = a_o\left(\frac{K+1}{K-1}x_r + \frac{K-3}{K-1}x_i - 1)\right) \quad . \quad (6)$$

The original amplitudes of the waves are restored after crossing.

Part I.—The Crossing of Two Oppositely Moving Waves at a Pipe Enlargement Under Isentropic Conditions of Flow

Two oppositely moving waves AA, BB (Fig. 4) of amplitudes x_i and x_r respectively cross at a pipe enlargement. After crossing the enlargement the amplitudes of waves AA and BB change to x'_i and x'_r respectively and the equations of flow are then given by :

Particle velocity to right of enlargement

$$\overrightarrow{U_R} = \frac{2}{K-1}a_o(x'_i - x_r) \quad . \quad . \quad . \quad (7)$$

particle velocity to left of enlargement

$$\overrightarrow{U_L} = \frac{2}{K-1}a_o(x_i - x'_r) \quad . \quad . \quad . \quad (8)$$

Energy equation across enlargement

$$\tfrac{1}{2}(U^2_L - U^2_R) = \frac{K}{K-1}\left(\frac{p_R}{\rho_R} - \frac{p_L}{\rho_L}\right) \quad . \quad . \quad . \quad . \quad (9)$$

where R, L refer to conditions to right and left of enlargement respectively.

Also continuity equation across enlargement

$$U_L\rho_L A_L = U_R\rho_R A_R \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

But

$$(p_L/p_O)^{\frac{K-1}{2K}} = x_i + x'_r - 1 \quad . \quad . \quad . \quad (i)$$

and

$$(p_R/p_O)^{\frac{K-1}{2K}} = x'_i + x_r - 1 \quad . \quad . \quad . \quad (ii)$$

and for isentropic flow :

$$p_L/\rho^K_L = p_R/\rho^K_R = p_O/\rho^K_O \quad . \quad (iii)$$

where

$$Kp_O/\rho_O = a^2_O \quad . \quad . \quad . \quad . \quad (iv)$$

Making use of Equations (i), (ii),, (iii), (iv) it can be shown that Equations (9), (10) can be rewitten in the form :

$$\frac{2}{K-1}[(x_i - x'_r)^2 - (x'_i - x_r)^2] = (x'_i + x_r - 1)^2 - (x_i + x'_r - 1)^2 \quad . \quad (9A)$$

and

$$(x'_i - x_r)(x'_i + x_r - 1)^{2/K-1}\frac{A_R}{A_L} = (x_i - x'_r)(x_i + x'_r - 1)^{2/K-1} \quad . \quad (10A)$$

For predetermined values of A_R/A_L, K Equations (9A), (10A) may be solved simultaneously to compute the values of x'_i and

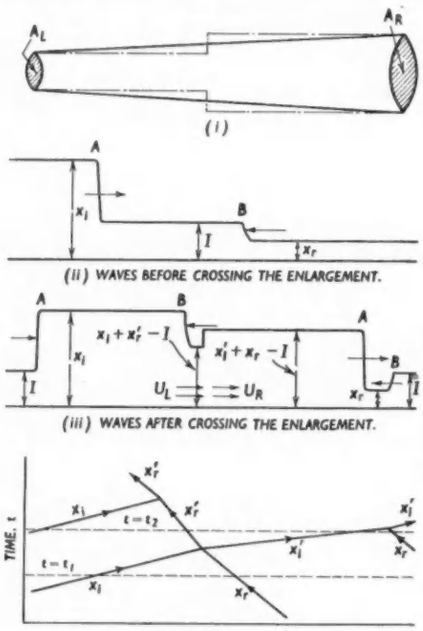

Fig. 4

x'_r namely the amplitudes of the waves transmitted after crossing when the amplitudes x_i and x_r of the waves prevailing prior to crossing are known. Equations (9A), (10A) being non-linear the solution is not simple. The application of the following procedure however allows a correlation of the dependent and independent variables in a convenient form.

Denoting the resultant pressure ratios in the narrow and large pipe sections by α and β respectively then :

$$\alpha = x_i + x'_r - 1 \quad . \quad . \quad . \quad . \quad . \quad (v)$$

and

$$\beta = x'_i + x_r - 1 \quad . \quad . \quad . \quad . \quad (vi)$$

Substituting in Equations (9A) and (10A) these equations become

$$\frac{2}{K-1}[(x_i - x'_r)^2 - (x'_i - x_r)^2] = \beta^2 - \alpha^2 \quad . \quad . \quad . \quad . \quad . \quad (9B)$$

$$(x'_i - x_r)\beta^{2/K-1}\frac{A_R}{A_L} = (x_i - x'_r)\alpha^{2/K-1} \quad . \quad (10B)$$

Eliminating $(x_i - x'_r)$ from Equations (9B), (10B) gives :

$$(x'_i - x_r) = \pm\left[\frac{\beta^2 - \alpha^2}{\left[\left(\frac{\beta}{\alpha}\right)^{4/K-1}\left(\frac{A_R}{A_L}\right)^2 - 1\right]\frac{2}{K-1}}\right]^{\frac{1}{2}} \quad . \quad . \quad . \quad (11)$$

which upon substitution in Equation (10B) reduces to :

$$(x_i - x'_r) = \pm\left[\frac{\beta^2 - \alpha^2}{\left[\left(\frac{\beta}{\alpha}\right)^{4/K-1}\left(\frac{A_R}{A_L}\right)^2 - 1\right]\frac{2}{K-1}}\right]^{\frac{1}{2}}\left(\frac{\beta}{\alpha}\right)^{2/K-1}\frac{A_R}{A_L} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Hence eliminating x'_r from Equations (v), (12) :

$$x_i = \tfrac{1}{2}\left[(\alpha+1) \pm \left\{\frac{\beta^2 - \alpha^2}{\left[\left(\frac{\beta}{\alpha}\right)^{4/K-1}\left(\frac{A_R}{A_L}\right)^2 - 1\right]\frac{2}{K-1}}\right\}^{\frac{1}{2}}\left(\frac{\beta}{\alpha}\right)^{2/K-1}\frac{A_R}{A_L}\right] \quad . \quad . \quad . \quad . \quad . \quad (13)$$

while from Equations (vi), (11) eliminating x'_i

$$x_r = \tfrac{1}{2}\left[(\beta+1) \mp \left\{\frac{\beta^2 - \alpha^2}{\left[\left(\frac{\beta}{\alpha}\right)^{4/K-1}\left(\frac{A_R}{A_L}\right)^2 - 1\right]K-1}\right\}^{\frac{1}{2}}\right] \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The substitution of a pair of values of α, β ($\alpha < \beta$) in Equations (13), (14) gives for known values of A_R/A_L, K two pairs of values of x_i and x_r. It can be shown that one pair of these leads to rightward flow (i.e. flow having rightward particle velocities) while the other pair applies for leftward flow.

The method of representation suggested is as follows. Families of curves of constant values of α and β are drawn for predetermined values of A_R/A_L, K in axes of x_i and x_r. From such construction the values of α and β associated with a given pair of values of x_i and x_r can be determined. The values of α and β so obtained can then be applied to calculate the corresponding values of x'_i and x'_r when use is made of the relationships given by Equations (v), (vi).

Fig. 5 shows the suggested representation for $A_R/A_L = 1{\cdot}1$ and $K = 1{\cdot}38$.

Criterion for Reversal of Flow

Fig. 5 involves two different types of flow rightward and leftward flow. The direction of flow reverses when :

$$U_R = U_L = 0$$

From Equations (7), (8), (9B) this occurs when :

$$\beta^2 - \alpha^2 = 0$$

or when

$$\beta = \alpha \quad . \quad . \quad . \quad . \quad (15)$$

β, α always being positive.

Substituting from Equation (15) in Equations (13), (14), the criterion for reversal of flow is given by :

$$\left.\begin{aligned} x_i &= \tfrac{1}{2}(\alpha+1) \\ \text{and} \quad x_r &= \tfrac{1}{2}(\beta+1) \end{aligned}\right] \quad . \quad . \quad . \quad . \quad (vii)$$

Hence from Equations (15), (vii) the criterion is :

$$x_i = x_r \quad . \quad . \quad . \quad . \quad . \quad (16)$$

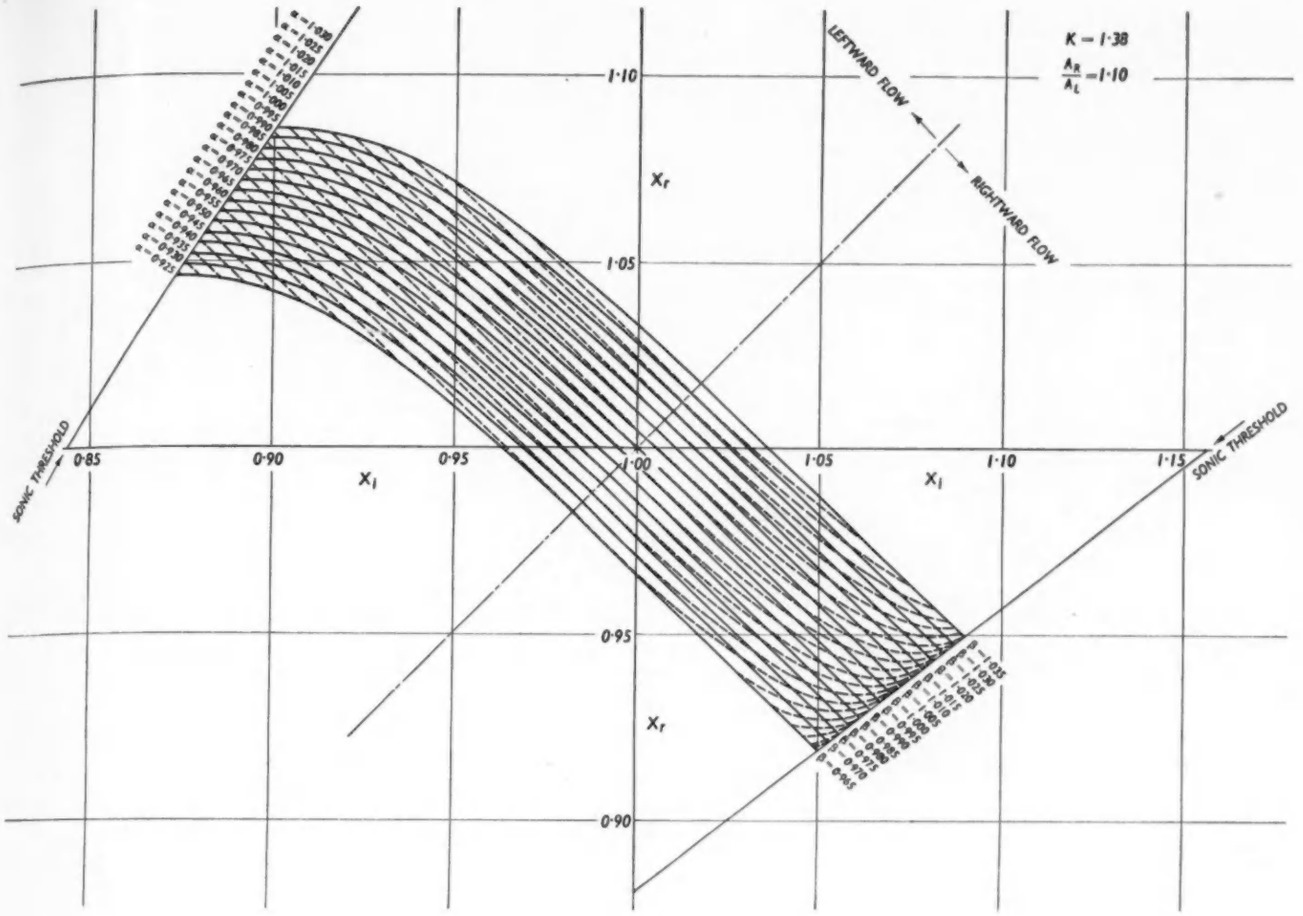

Fig. 5

Equation (16) indicates that the boundary for reversal of flow in Fig. 5 is a straight line equally inclined to the x_i and x_r axes. Evidently from Equation (15) the points of contact of pairs of α and β curves of equal parameters lie on that line.

Sonic Boundary

Waves of comparatively large amplitudes travelling in pipes of variable area eventually lead to sonic flow. Two patterns of sonic flow are distinguished, rightward and left-

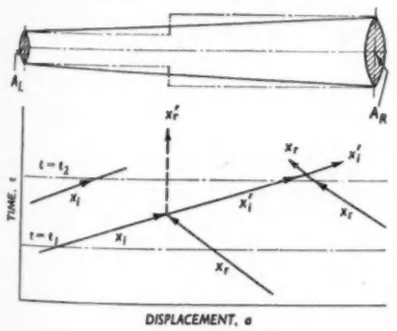

Fig. 6

ward sonic flow (simulating the divergent and convergent portions of a De Laval nozzle).

Notice may be taken of the fact that in the case of a parallel pipe enlargement sonic flow is only confined to the mouth of the smaller pipe.

Referring to Fig. 6 two oppositely moving waves of amplitudes x_i and x_r cross at the enlargement so that the flow is just sonic. After crossing has taken place the particle velocity to the right of the enlargement is given by :

$$\overrightarrow{U_R} = \pm\frac{2}{K-1}a_o(x'_i - x_r) \quad . \quad . \quad \text{(viii)}$$

for rightward and leftward flow respectively while the corresponding particle velocity immediately to the left of the enlargement :

$$\overleftarrow{U_L} = \pm\frac{2}{K-1}a_o(x_i - x'_r) \quad . \quad . \quad . \quad \text{(ix)}$$

But under sonic conditions this velocity is equal to the local acoustic velocity. Hence for rightward and leftward sonic flow :

$$\pm\frac{2}{K-1}a_o(x_i - x'_r) = a_o(x_i + x'_r - 1) \quad . \quad \text{(x)}$$

Thus from Equation (x) rightward sonic flow occurs when

$$x'_r = \left(\frac{3-K}{1+K}x_i + \frac{K-1}{K+1}\right) . \quad . \quad . \quad (17)$$

and

$$\overrightarrow{U_L}\,(\text{sonic}) = \frac{2}{K+1}a_o(2x_i - 1) \quad . \quad . \quad . \quad (18)$$

Also leftward sonic flow takes place when :

$$x'_r = \left(\frac{1+K}{3-K}x_i - \frac{K-1}{3-K}\right) . \quad . \quad . \quad (19)$$

and

$$\overleftarrow{U_L}\,(\text{sonic}) = \frac{2}{3-K}a_o(2x_i - 1) \quad . \quad . \quad . \quad (20)$$

Making use of the sonic relationship given by Equation (x), the energy equation (9*A*) can be rewritten for flow under sonic conditions, this is given by :

$$\frac{K+1}{K-1}(x_i + x'_r - 1)^2 - \left[\pm\frac{2}{K-1}(x'_i - x_r)\right]^2 = \frac{2}{K-1}(x'_i + x_r - 1)^2 \quad . \quad \text{(xi)}$$

for rightward and leftward sonic flow respectively.

Similarly the continuity Equation (10*A*) under these conditions reduces to :

$$\frac{A_L}{A_R}\,\frac{x_i + x'_r - 1}{\pm\frac{2}{K-1}(x'_i - x_r)} = \left(\frac{x'_i + x_r - 1}{x_i + x'_r - 1}\right)^{2/K-1} \quad . \quad . \quad . \quad . \quad . \quad \text{(xii)}$$

Dividing Equation (xi) by $(x_i + x'_r - 1)^2$ which $\times 0$ therefore :

$$\frac{K+1}{K-1} - \left[\frac{\pm\frac{2}{K-1}(x'_i - x_r)}{x_i + x'_r - 1}\right]^2 = \frac{2}{K-1}\left(\frac{x'_i + x_r - 1}{x_i + x'_r - 1}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad \text{(xi}(a)\text{)}$$

Solving Equations (xii), (xi(*a*)) to eliminate

$$\frac{(x_i + x'_r - 1)}{\pm\frac{2}{K-1}(x'_i - x_r)},$$

putting the pressure ratio across the enlargement

$$\frac{x_i' + x_r - 1}{x_i + x_r' - 1} = \gamma \quad . \quad . \quad . \quad (21)$$

the following relationship is obtained :

$$\frac{K+1}{K-1} - \frac{(A_L/A_R)^2}{\gamma^{4/K-1}} = \frac{2}{K-1}\gamma^2 \quad . \quad (22)$$

Equation (22) gives for a certain gas the relation ship between the area ratio A_R/A_L and the pressure ratio γ associated with both types of sonic flow. This relationship is plotted in Fig. 7 for $K = 1{\cdot}38$.

Eliminating x'_i and x'_r from Equation (xii) using Equations (21) and (17) the relationship defining the boundary for rightward sonic flow is obtained namely :

$$\frac{2(2x_i - 1)}{K+1}\left[\gamma - \frac{A_L/A_R}{\frac{2}{K-1}\gamma^{2/K-1}}\right] = 2x_r - 1 \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Technical Contributors Section (*continued*)

Similarly from Equations (xii), (21), (19) the equation of the sonic boundary for leftward flow is :

$$\frac{2}{3-K}(2x_i-1)\left[\gamma+\frac{A_L/A_R}{\frac{2}{K-1}\gamma^{2/K-1}}\right]=2x_r-1 \quad . \quad . \quad . \quad . \quad . \quad (24)$$

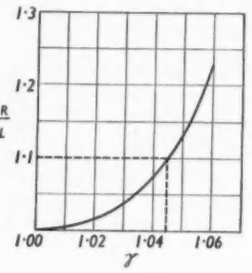

Fig. 7—Solution of equation (22) for $K=1{\cdot}38$

Equations (23), (24) describe straight line relationships between x_i and x_r. This can be seen from Fig. 5.

Part II.—The Crossing of Two Oppositely Moving Waves at the Surface of Separation Between Two Different Gas Layers under Isentropic Conditions of Flow

When two oppositely moving waves cross at the surface of separation between two gas layers of different nature or state a process of partial reflection occurs. The following analysis enables the correlation of the initial wave amplitudes, namely those prevailing before crossing with the corresponding amplitudes obtained after crossing.

In Fig. 8 two oppositely moving waves *BB* and *DD* cross at the surface of separation *AA* between two different gas layers. The gas layer to the right of *AA* has an isentropic index K_R and an undisturbed acoustic velocity a_{oR}, the relevant values for the gas layer to the left of *AA* being K_L and a_{oL}.

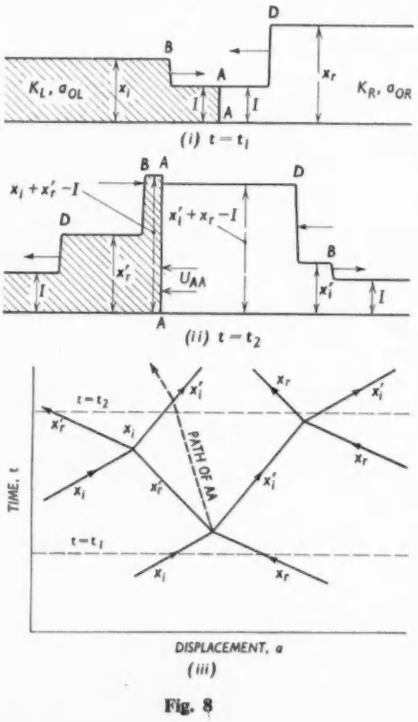

Fig. 8

Immediately before crossing the amplitudes of the rightward moving wave *BB* and leftward moving wave *DD* are given by :

$x_i=(p_i/p_o)^{K_L-1/2K_L}$ and $x_r=(p_r/p_o)^{K_R-1/2K_R}$

respectively

while instantly after crossing the transmitted amplitudes of these same waves assume the values :

$x'_i=(p'_i/p_o)^{K_R-1/2K_R}$ and $x'_r=(p'_r/p_o)^{K_L-1/2K_L}$

respectively.

After crossing has occurred the particle velocity to the right of *AA* is given by :

$$\overrightarrow{U_R}=\frac{2}{K_R-1}a_{oR}(x'_i-x_r) \quad . \quad . \quad (xiii)$$

and the particle velocity to the left of *AA*.

$$\overrightarrow{U_L}=\frac{2}{K_L-1}a_{oL}(x_i-x'_r) \quad . \quad . \quad (xiv)$$

In the absence of diffusion effects :

$$U_R=U_L=\text{velocity of } AA$$

Hence from Equations (xiii), (xiv) :

$$(x'_i-x_r)=\frac{a_{oL}(K_R-1)}{a_{oR}(K_L-1)}(x_i-x'_r) \quad . \quad . \quad (25)$$

But the resultant pressure p_R to the right of *AA* is given by :

$$(p_R/p_o)^{K_R-1/2K_R}=x'_i+x_r-1 \quad . \quad . \quad . \quad (xv)$$

While to the left of *AA* the resultant pressure p_L follows from :

$$(p_L/p_o)^{K_L-1/2K_L}=x_i+x'_r-1 \quad . \quad . \quad . \quad (xvi)$$

With no pressure discontinuity

$$p_R=p_L$$

hence from Equations (xv), (xvi)

$$x'_i+x_r-1=(x_i+x'_r-1)^{\frac{K_L(K_R-1)}{K_R(K_L-1)}} \quad . \quad . \quad . \quad . \quad . \quad (26)$$

Writing :

$$\frac{a_{oL}(K_R-1)}{a_{oR}(K_L-1)}=\delta \text{ and } \frac{K_L(K_R-1)}{K_R(K_L-1)}=\phi$$

Equations (25), (26) can now be rewritten as :

$$(x'_i-x_r)=\delta(x_i-x'_r) \quad . \quad . \quad . \quad (25A)$$

$$(x'_i+x_r-1)=(x_i+x'_r-1)^{\phi} \quad . \quad . \quad (26A)$$

For known values of δ and ϕ (namely of K_R, K_L, a_{oR}, a_{oL}) and for a given pair of values of x_i and x_r Equations (25*A*), (26*A*) can be solved simultaneously to compute the corresponding values of x'_i and x'_r. These equations being non-linear the solution is rather tedious and the following method is suggested.

Assume appropriate pairs of values of x_i and x'_r, substitute these values in Equations (25*A*), (26*A*) to get the corresponding values of x'_i and x_r. Draw in axes of x'_i and x_r two families of curves of constant x_i and x'_r. This construction enables the determination of the transmitted amplitudes x'_i and x'_r when the initial amplitudes x_i and x_r are known.

The proposed construction is given in Fig. 9 for values of $K_R=1{\cdot}4$, $K_L=1{\cdot}32$, $a_{oR}=1150$ft per second, $a_{oL}=1890$ft per second. These figures represent typical values for flow in the exhaust pipe of a two-stroke cycle compression ignition engine.

Fig. 9 indicates that curves of constant x_i and x'_r are almost linear. This can be explained by the fact that second and higher orders of (x_i-1) and (x'_r-1) reducing from the binomial expansion of $(x_i+x'_r-1)^{\phi}$

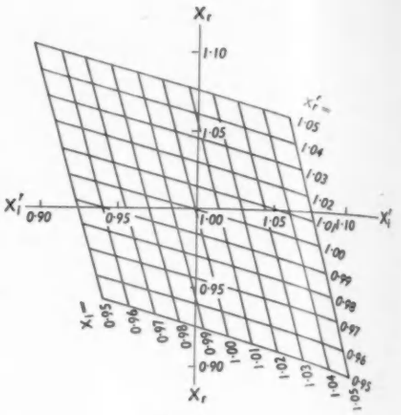

Fig. 9

in Equation (26*A*) are negligibly small. Thus with these terms eliminated :

$$(x_i+x'_r-1)^{\phi}=1+\phi(x_i+x'_r-2) \quad . \quad (xvii)$$

Hence substituting from Equation (xvii) in Equation (26*A*)

$$(x'_i+x_r-2)=\phi(x_i+x'_r-2) \quad . \quad . \quad (26B)$$

Equations (25*A*) and (26*B*) can now be solved simultaneously to derive the value of the dependent flow parameters x'_i and x'_r. This solution ultimately gives :

$$x'_i=\frac{2x_i\left(\frac{K_R-1}{K_L-1}\right)+x_r\left(\frac{a_{oR}}{a_{oL}}-\frac{K_R}{K_L}\right)+2\left(\frac{K_R}{K_L}-\frac{K_R-1}{K_L-1}\right)}{\frac{a_{oR}}{a_{oL}}+\frac{K_R}{K_L}} \quad . \quad . \quad (27)$$

$$x'_r=\frac{2x_r\left(\frac{K_L-1}{K_R-1}\right)+x_i\left(\frac{a_{oL}}{a_{oR}}-\frac{K_L}{K_R}\right)+2\left(\frac{K_L}{K_R}-\frac{K_L-1}{K_R-1}\right)}{\frac{a_{oL}}{a_{oR}}+\frac{K_L}{K_R}} \quad . \quad . \quad (28)$$

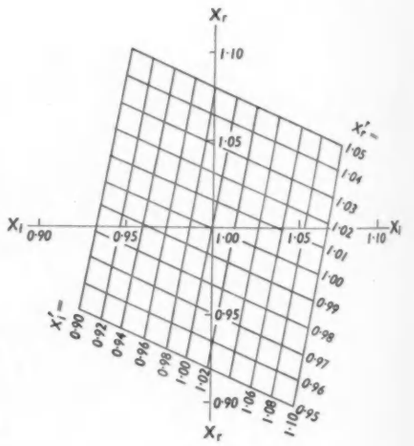

Fig. 10

These relationships suggest an alternative, but more suitable representation to that shown in Fig. 9. This latter construction given in Fig. 10 has lines of constant x'_i and x'_r drawn in axes of x_i and x_r for values of K_R, K_L, a_{oL}, a_{oL} equal to those associated with Fig. 9.

Note

Special Case of Head of Steep-Fronted Wave Moving in Undisturbed Gas.—Isentropic state relationships very approximately

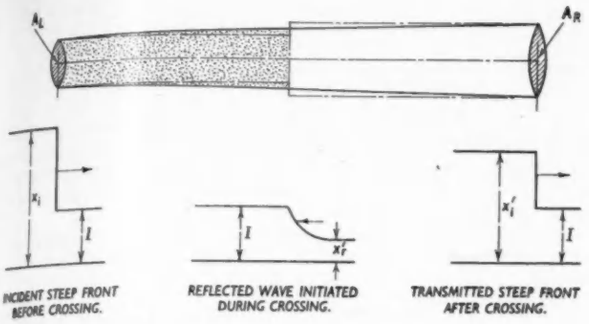

Fig. 11

hold for the head of a steep-fronted wave of small or moderate amplitude.[1] Figs. 5, 10 can therefore be used to compute changes undergone by that steep front when it is subject to conditions similar to those outlined in the previous analysis.

The values of the initial wave amplitudes fed to Figs. 5, 10, in such a case would be the initial amplitude of the steep front x_i and a value of x_r equivalent to unity, this latter value denoting that the steep front is being propagated in indisturbed gas (Fig. 11). The transmitted wave amplitudes obtained from Figs. 5 and 10 would be the modified amplitude of the steep front x'_i and the amplitude of the reflected wave x'_r initiated at that front.

These same results could have been obtained from an alternative mathematical treatment basically similar to that given before but in which a value of unity is assigned to x_r. This treatment however would advantageously allow the derivation of x'_i and x'_r directly in terms of x_i.

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Use of an Optimising Technique in Engineering Problems

By C. STOREY

A discussion is given of the way in which a numerical hill-climbing technique may be used in the solution of a number of engineering problems. Applications include optimum design, solution of sets of non-linear algebraic equations and problems which can be put into a variational form. As a numerical example torsion in a rectangular bar is considered.

THE object of this article is to emphasise the importance to engineers of an efficient numerical hill-climbing technique capable of dealing with variables that may be restricted in their ranges. The first section is devoted to a brief description of how the technique is used. The second section deals with the kind of problem in which such an optimising technique may be applied. Finally an example is considered.

Numerical Method

This is fully described in Reference 1, so it is unnecessary to describe it in detail here. It is of interest, however, to mention the way in which one would use it to solve a problem.

The calculations are programmed in the Ferranti Mercury Autocode. The programme is so organised that the only changes required in going from one problem to another consist of writing a new last chapter and putting in the correct directives. The last chapter contains simply the Autocode programme for calculating the function being optimised in terms of its parameters. The computer is fed with the complete programme and it seeks the optimum value of the function, printing out at intervals its current value and the corresponding values of the variables.

It is necessary to estimate the number of steps to get to the required optimum, since, not knowing the answer in advance, the machine does not know how far it is from the solution. A measure of the progress being made is printed out at each stage and should this indicate, at the end of a calculation, that the optimum has not yet been reached, the programme may be restarted using the final values of the parameters as new starting values. A comparison of this and other methods of optimising is given in Reference 8.

Applications

A discussion is now given of some of the more important engineering problems in which it is necessary to choose either sets of parameters or complete functions in such a way as to maximise or minimise an expression depending on them.

Best Design

In design one is often faced with the problem of choosing the best possible design from those that merely fit the specifications. Best, in this context, may take on a number of meanings. Thus, it may be required to find the steel structure with minimum weight, the plant which has minimum cost per unit output[7, 8] or the operating strategy to give maximum profit.

A good illustration of this type of application occurs in the design of I beams. It is required to find the minimum weight of beam to comply with simultaneous conditions of failure due to local buckling of the compression element and to direct bending stresses. Thus for a beam with dimensions as shown in Fig. 1 : the area

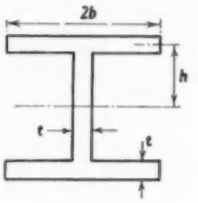

Fig. 1

of cross section A, which has to be minimised is given by

$$A=2t\,(2b+h) \quad . \quad . \quad . \quad . \quad (1)$$

The failure conditions which the parameters in (1) must also satisfy are

$$(a)\ \text{by local buckling } \left(\frac{t}{b}\right)^2=\frac{\sigma y}{KE} \quad . \quad . \quad (2)$$

$$(b)\ \text{by bending } \frac{I}{h}\left(\frac{t}{b}\right)^2=\frac{M}{KE} \quad . \quad . \quad . \quad . \quad (3)$$

where

K=Local buckling constant

σy=Yield stress

E=Young's modulus

I=Moment of inertia

and

M=External bending moment

Thus A must be minimised with respect to the variables h, b and t and subject to the constraints (2) and (3).

This problem is dealt with analytically by S. Krishman and K. V. Shetty in Reference 2. They assume that web thickness and flange thickness are equal and that the section is thin walled. Introducing a new variable k by $h=bk$ and using a single Lagrange multiplier they are able to deal with the constraints.

If, however, they had not been able to make these simplifying assumptions and if (2) and (3) had been inequalities rather than equalities analytical solution would have been much more difficult if not impossible. It is in such situations that the technique discussed here is invaluable.

Other examples of this nature occur in the solution of optimising problems occuring in aeronautics see for example Reference 3.

Solution of Simultaneous Algebraic Equations

Sets of more than, say, five algebraic simultaneous equations are difficult to solve by hand. In the case of linear equations computer programmes exist for quite large sets. If, however, the equations are non-linear then some form of iterative procedure is needed for their solution.

The hill-climbing technique can be used in the solution of such equations in the following way. The equations are first written in the form

$$\phi_i\,(x_i)=0 \quad i=1, 2\,..\,n \quad . \quad . \quad . \quad (4)$$

the x_i's being the unknowns.

Then the sum

$$\Phi=\sum_i\{\phi_i\,(x_i)\}^2 \quad . \quad . \quad . \quad . \quad (5)$$

is formed. The values of the x_i's which make Φ a minimum (equal to zero) are the required solutions of Equations (4). Non-linear equations will, of course, have more than one solution and care may be needed

Technical Contributors Section *(continued)*

in the selection of the starting values of the x_i's.

Closely allied to this application is the fitting of non-linear models to experimental data. In this case the parameters in the model are chosen so as to minimise the sum of the squares of the deviations directly. The results of setting the partial derivatives of this sum equal to zero would be to produce a set of non-linear equations.

Variational Problems

The equations describing many physical and engineering systems can be obtained from the condition that a certain functional (that is a function of one or more other functions) should be stationary. That is to say, the application of the classical theory of the calculus of variations to this functional will simply recover the equations of the system. Examples of such stationary principles are minimum potential energy for elastic systems (linear and non-linear), minimum heat dissipation in electrical networks, Hamilton's principle in mechanical systems, &c. Similar principles have also been formulated in problems of heat transfer, hydromechanics, thermodynamics and other such fields[5,4]. Another important use of stationary principles is in the determination of eigenvalues by the use of the so called " Rayleigh's Quotient."

The variational form of the above problems may be used to obtain a direct solution in the following manner. The function that has to be chosen so as to make the functional of the system stationary is expanded in an appropriate form. It is then substituted in the functional which is partially differentiated with respect to the coefficients of the expansion. These partial derivatives are then set equal to zero, and the resulting algebraic equations solved to obtain the coefficients. By an appropriate form of expansion is meant one that will satisfy the necessary boundary conditions, take full account of any symmetry properties and result in linear equations for the coefficients. It is also necessary to obtain an expansion that will approximate to the actual function with as few terms as possible.

The alternative approach to partial differentiation is the use of the hill-climbing technique to minimise the functional directly with respect to the coefficients of the expansion. By this method one is not necessarily restricted to using expansions that would result in linear equations.

Numerical Application

Consider a rectangular bar with cross section as shown in Fig. 2.

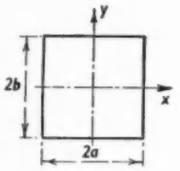

Fig. 2

The required stress function ϕ must minimise the strain energy

$$u=\iint\left\{\tfrac{1}{2}\left[\left(\frac{\partial\phi}{\partial x}\right)^2+\left(\frac{\partial\phi}{\partial y}\right)^2\right]-2G\theta\phi\right\}dxdy \quad . \; . \; . \; . \; (6)$$

where the notation of Timoshenko[6] has been used. The boundary conditions are that Φ should vanish on $x=\pm a$ $y=\pm b$ Using these boundary conditions and symmetry considerations a suitable stress function is seen to be of the form

$$\phi=(x^2-a^2)\,(y^2-b^2)\,\Sigma\Sigma a_{mn}x^m y^n \quad . \; . \; (7)$$

where m and n are even integers and a_{mn} are coefficients which must be chosen to make u a minimum.

The normal method of procedure is to substitute for ϕ in (6), carry out the differentiations and integration, differentiate the resulting expression with respect to the a's and solve the set of simultaneous linear algebraic equations so obtained. The present method, however, simply treats u as the function to be written in the final chapter of the optimising programme.

As a practical example only two coefficients were taken i.e. a stress function of the form

$$\phi=(x^2-a^2)\,(y^2-b^2)\,[a_o+a_1\,(x^2+y^2)]$$

was used. The bar was assumed to have a square cross section with unit side and $G\theta$ was taken equal to unity. The table below shows how the computing machine progressed from the starting values of a_o and a_1, to the final optimum values. It also shows the results obtained by the solution of the simultaneous equations.

Table

	a_o	a_1
Starting	0·500,00	0·500,00
1st stage	0·480,00	0·318,00
2nd stage	0·518,10	0·247,60
3rd stage	0·579,41	0·125,36
4th stage	0·582,28	0·121,425
5th stage	0·584,37	0·118,49
Optimum	0·584,37	0·118,49
Simultaneous equations ...	0·584,39	0·118,46

The machine time for these computations was about two minutes.

Acknowledgment

The author would like to thank the Directors of Constructors John Brown Ltd., for permission to publish this article.

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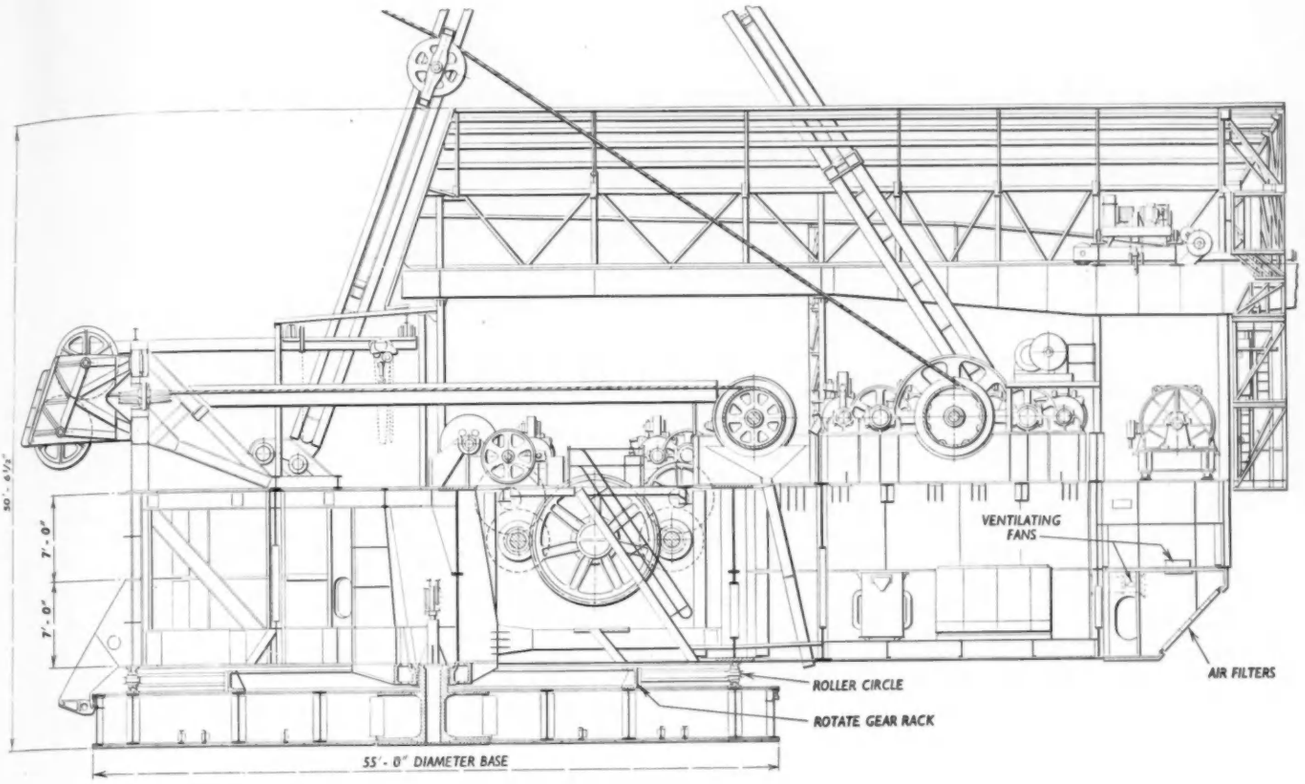
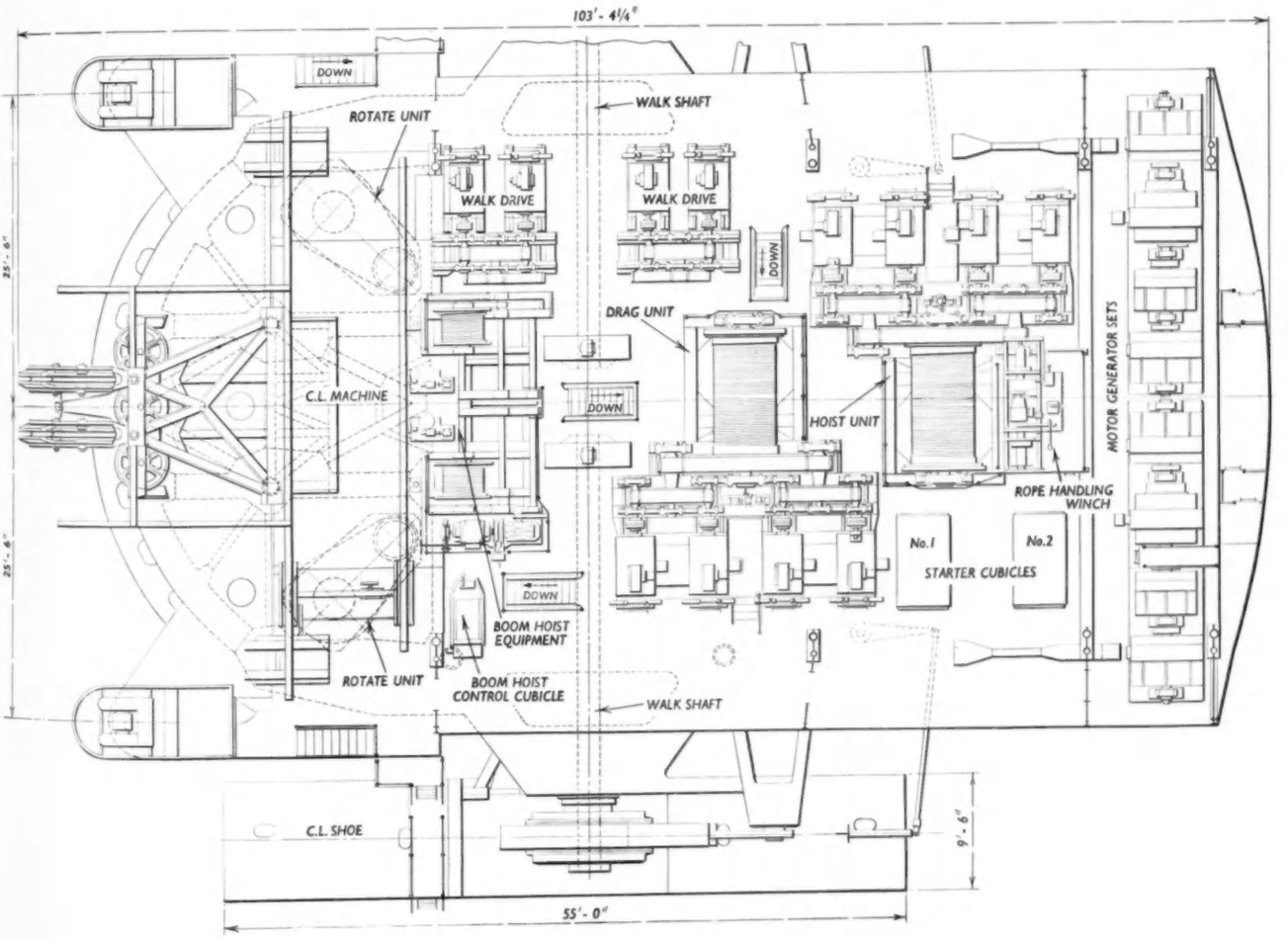
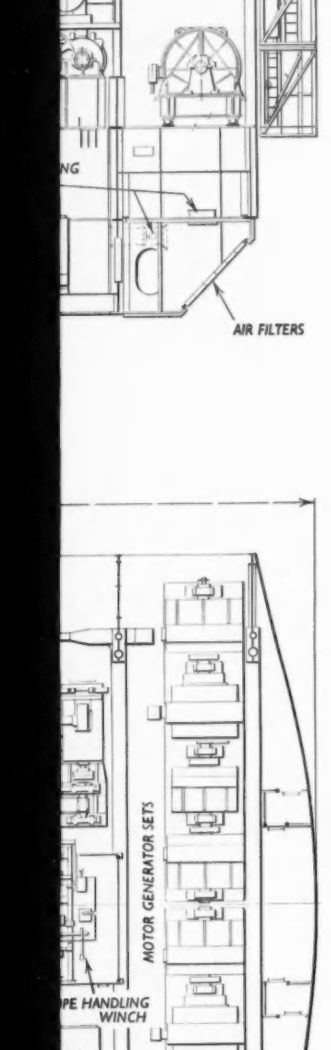
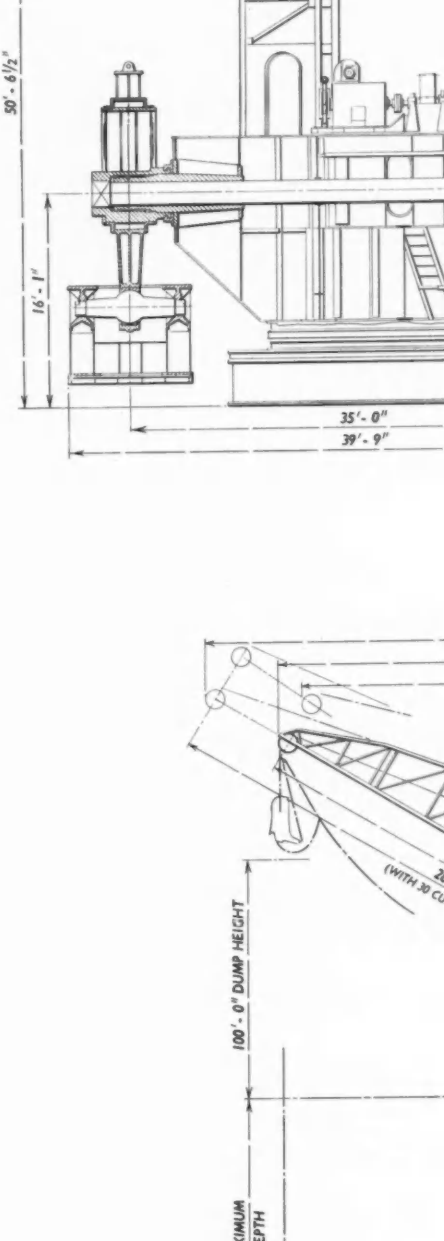
40 CUBIC YARD WALKI

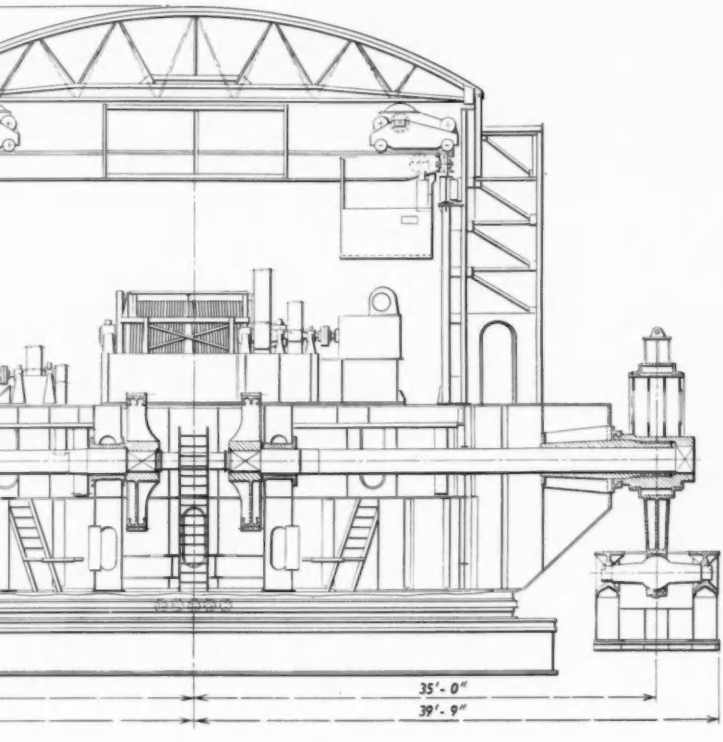


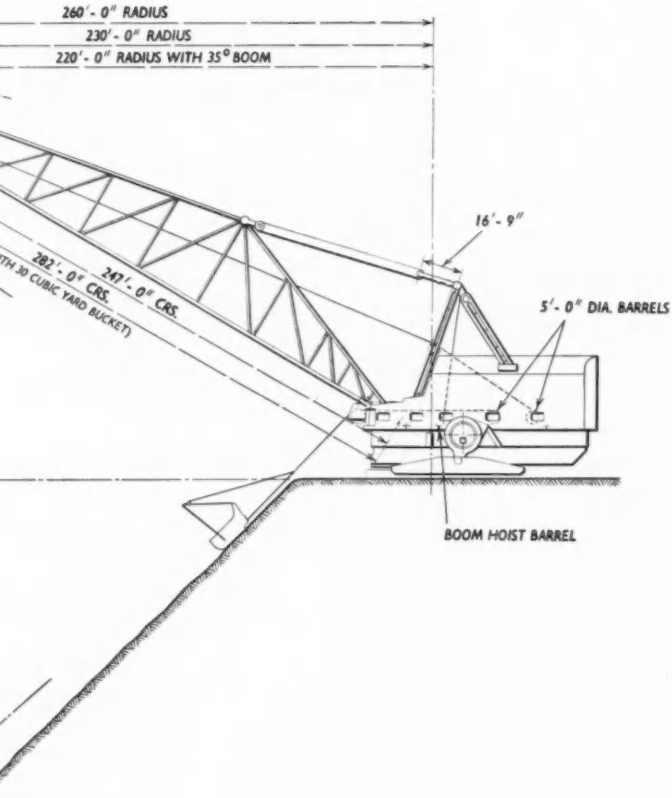


RD WALKING DRAGLINE






35'- 0"
39'- 9"


260'- 0" RADIUS
230'- 0" RADIUS
220'- 0" RADIUS WITH 35° BOOM
16'- 9"
282'- 0" CRS.
247'- 0" CRS.
5'- 0" DIA. BARRELS
BOOM HOIST BARREL

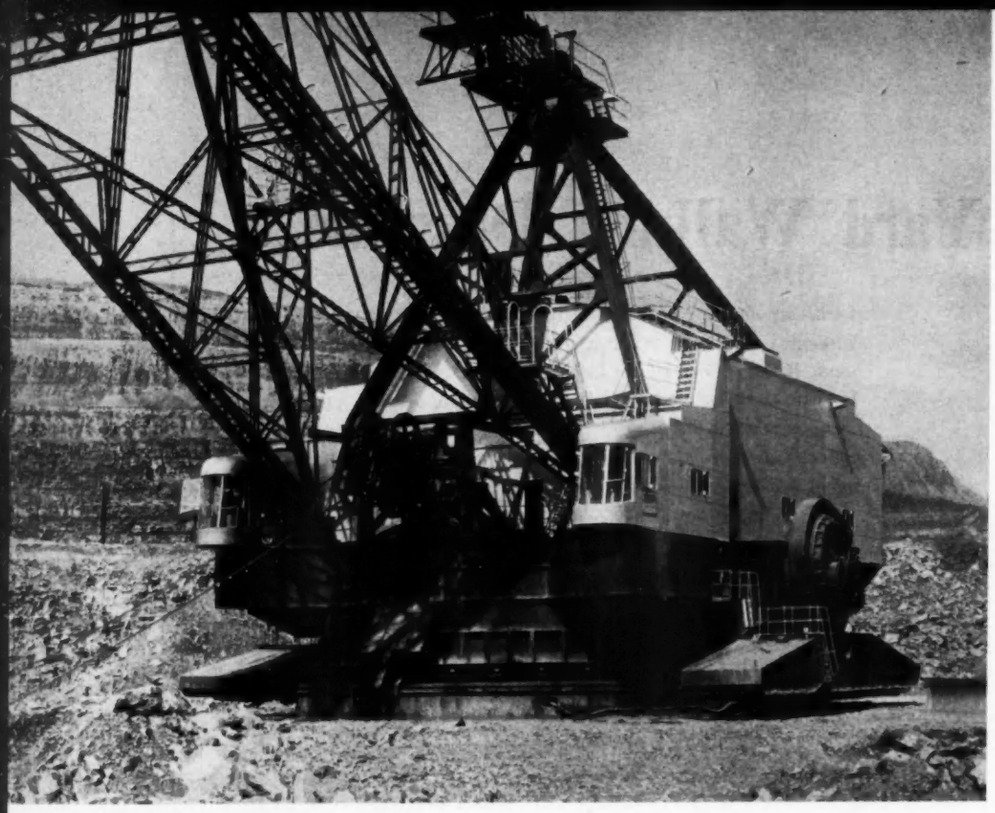
40 Cubic Yard Walking Dragline

FOR OPEN-CAST COAL MINING AT MAESGWYN CAP, S. WALES

A walking dragline of 40 cubic yards capacity recently placed in service by the National Coal Board in the open-cast workings at Maesgwyn Cap, Glyn Neath, South Wales, is one of the largest machines of its kind in the world. This new dragline, designed and built by Ransomes and Rapier, Ltd., weighs about 1800 tons and when working under favourable conditions, is capable of handling about the equivalent of its own weight of overburden in an hour. Two similar machines are also being built—one for Stewarts and Lloyds, Ltd., and one for the United Steel Companies, Ltd.

TEN years ago Ransomes and Rapier, Ltd., of Ipswich, designed and built the first of its "W1400" walking draglines for Stewarts and Lloyds, Ltd., and at that time this 20 cubic yard capacity machine was the largest of its kind in the world. It is still in service together with several similar large machines, built subsequently for firms in this country and overseas. Based upon the specialised knowledge acquired from the "W1400" Ransomes and Rapier, Ltd. (now part of the Newton, Chambers Group), has now designed and built a 40 cubic yard capacity walking dragline, known as the "W1800." The first of these new machines has been purchased by the National Coal Board and was recently placed in service removing overburden at the open-cast coal workings at Maesgwyn Cap, Glyn Neath, in South Wales, where it is being operated by George Wimpey and Co., Ltd.

Although the new dragline, as can be seen in the drawings and photographs we reproduce, has a layout and appearance generally similar to the earlier machines it incorporates a number of important changes based upon design experience and to comply with the particular requirements of the application. Previous heavy-duty machines of the design were of all-welded construction as they are intended to complete their full working life on one site. This machine, when work at the present site is completed, will have to be dismantled, moved elsewhere and re-assembled. For this reason the whole of the structure has been built up from individual complete units. These units, the heaviest of which weighs 42 tons, are dowelled for



Front of walking dragline at Glyn Neath, showing the driver's cabins, one on each side of the superstructure

precise location on assembly when they are bolted together with "Torshear" friction grip bolts. Flange welding, used in site assembly of some of the structure to impart additional rigidity where required, is designed for ease of "cutting-out" in dismantling and welding in re-assembly without affecting adjoining parts of the main structure.

Leading Particulars of "W.1800" Walking Dragline

	30 cubic yards	40 cubic yards
Bucket capacity		
Length of boom, centre of pulley pin to centre of foot pin	282ft	247ft
Radius of discharge—vertical	260ft	230ft
Maximum allowable working load at maximum radius	65 tons	91 tons
Dump height at maximum radius (approximate) ...	130ft	100ft
Clearance radius of cab ...	69ft	69ft
Centres of shoes...	70ft	70ft
Area of base	2380 square feet	2380 square feet
Bearing pressure of base (average)	11·9 lb per square inch	11·8 lb per square inch
Working weight (approx.) (excluding bucket)	1790 tons	1765 tons

The superstructure loads were in the first of these large draglines distributed to the walking gear assembly through a deep transverse bridge girder forming an integral part of the superstructure. This bridge girder has now been replaced by the incorporation of two heavy transverse girders into the base frame of the superstructure. As an alternative to the welded tubular boom a bolted and pin jointed steel section boom, which can readily be dismantled and re-assembled, has been designed.

The dragline is electrically operated throughout under Ward-Leonard amplidyne control, power being supplied at 6600V by a trailing cable. Its leading particulars and working ranges can be seen in the table above and in the diagram with the drawings reproduced on the plate which accompanies this issue. Our illustrations give some impression of the size and weight of some of the major parts in the structure of the machine.

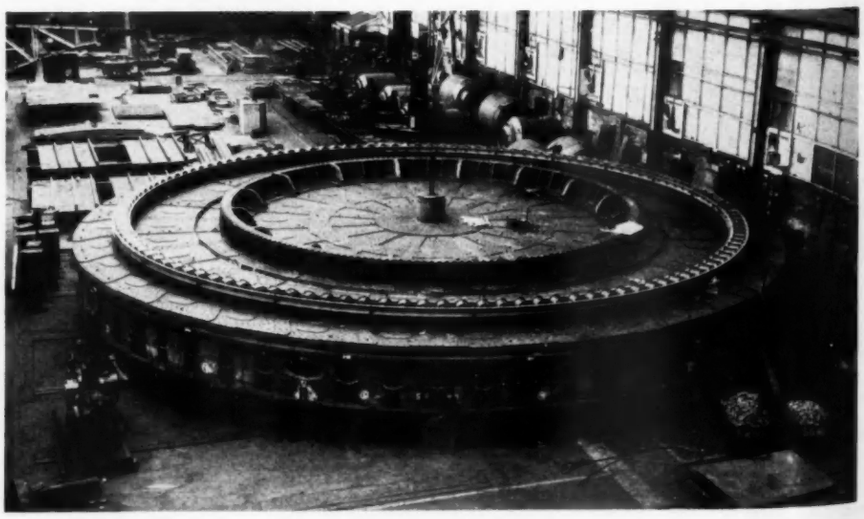
The dragline is fitted with a boom with a basic length of 208ft on which either of two extensions can be mounted—one to give an operating length of 282ft for working with a 30 cubic yard bucket and the other an operating length of 247ft for working with a 40 cubic yard bucket. In its present service the machine is operating with a 40 cubic yard "Esco" dragline bucket supplied by Hadfields, Ltd., and with its rigging this bucket alone weighs about 33 tons.

The duty cycle of the machine with the 40 cubic yard bucket is well worth noting—when digging to a depth of 40ft the dragline can load the bucket, hoist it to a dumping height of 40ft above ground level, swing through 90 deg., dump the load and return the bucket to the filling point in sixty-four seconds. On the same duty, but swinging the load through 120 deg., the cycle time is sixty-eight seconds, and when swinging through 180 deg., eighty-five seconds. Under optimum conditions the dragline can be expected to handle up to 1300 cubic yards (some 1750 tons) of material an hour or about the equivalent of its own weight. The fact that this duty cycle has to be maintained continually day in and day out is some indication of the problems which were involved in the machine's design and construction.

The base of the machine, which weighs 284 tons, has a diameter of 55ft with a depth of 4ft 2in between its top and bottom plates. It is a riveted, welded and bolted assembly of rolled steel plates and sections heavily braced and built up on sixteen full-depth radial girders to provide the rigid structure necessary to cope with the digging and walking duties of the machine. Forming an integral part of the base is the forged steel centre post upon which the superstructure revolves. This post, with an overall height of 6ft 3in, weighs over 4 tons and has a diameter of 2ft 4in on its projecting length of 2ft above the base to receive the bearing of the superstructure. Full depth circular girders in the base support the 33ft diameter rack and 48ft diameter roller path for the rotating superstructure.

The roller path is built up of cast nickel chromium molybdenum steel segments of bridge type rail section with a 9in face width. It supports the live ring roller circle comprising 125 alloy steel taper rollers, 10in diameter, mounted in a structural frame with heavy inner and outer channel members. Cast iron rollers bolted to the ring structural members serve as distance pieces for the main rollers. A heavy hook rail bolted under the top projecting flange of the outer main circumferential beam of the base structure distributes the lifting loads when the machine is walking. The rotate gear rack bolted to the base frame is an assembly of heat-treated cast steel segments and its 208 machined teeth have a 6in circumferential pitch with a face depth of 1ft 7½in.

The revolving superstructure, as in previous Rapier draglines, is a cantilever unit supported at one end on a ring of live rollers. It is built up on a rotate frame with an overall length of 94ft, a width of 69ft and a full depth of 14ft. This frame is made up of rolled steel plates and flats welded to form four full-length longitudinal girders into which are built circular girders for carrying the roller path. As already mentioned, the transverse bridge girder used in the "W.1400" machines to distribute the walking gear loads to the superstructure has been dispensed with, the loads now being taken by two transverse girders built into the frame and forming an integral part of the rigid structure. These 41ft long, 14ft deep girders, weighing 39 tons each, can clearly be seen in the photographs we reproduce showing the superstructure frame in course of erection at the maker's works. The wing girder assemblies for the walking gears mounted at the ends of the transverse girders, each weigh 42 tons and they are the heaviest individual members in the whole dragline structure. Top and bottom plates fitted over the main girder assembly complete a box structure sufficiently stiff to distribute and accommodate the heavy working and individual machinery loads with negligible deflections.



Base complete with the rotate gear rack and roller circle assembled at the maker's works

The main boom feet and front " A " frame legs are supported in welded bracket assemblies bolted to the frame where the main outer girders and the front transverse girder are connected to the circular girder through which the superstructure rests on the roller circle. To distribute effectively these localised loads over as many rollers as possible the areas where the brackets are connected to the frame are reinforced and doubling plates are incorporated in the webs of the circular girder.

The now generally familiar Cameron and Heath walking gear is used on the machine. The rectangular walking shoes, on each side of the machine, are brought into contact with the ground by eccentric-operated legs and in the walking operation the entire machine is tilted and slid along the ground in a series of steps in any desired direction. The two main walking shafts of this machine are machined nickel chrome molybdenum steel forgings, each 35ft 6in long by 1ft 9½in diameter and weighing 20 tons. These shafts only transmit torque, and all bending loads imposed by the walking eccentrics are taken by forged hollow steel axles, which are welded into the main transverse girders of the superstructure frame and wings.

The eccentrics are welded steel plate assemblies incorporating alloy steel castings which are bored and bronze bushed to rotate on the axles. The squared ends of the walking shafts fit into recesses machined in the bosses of these eccentrics. The outer surfaces of the eccentrics are machined to provide an inner race for a large roller bearing comprising a live ring of fifty-two rollers on which the walking leg is carried.

With a throw of 2ft 2in these eccentrics give a walking stride of 7ft 7in. The welded steel walking legs are coupled to the shoes through ankle connections giving a limited range of movement to the shoes in order that they can bear evenly when irregular terrain is being traversed. Leg links connect the top end of each leg to a pivot point on the wing girders projecting from the superstructure base. These links constrain the top end of each leg to move in an arc during revolutions of the walking eccentric. By this means the lower ends of the legs—the shoe axle centres—are constrained to describe an elliptical path, the major axis of which is approximately horizontal. The length of this major axis of the elliptical path is the length of each step imparted by eccentric rotation and the height of the minor axis is the lift of the shoe plus the lift of the walking shaft above the ground.

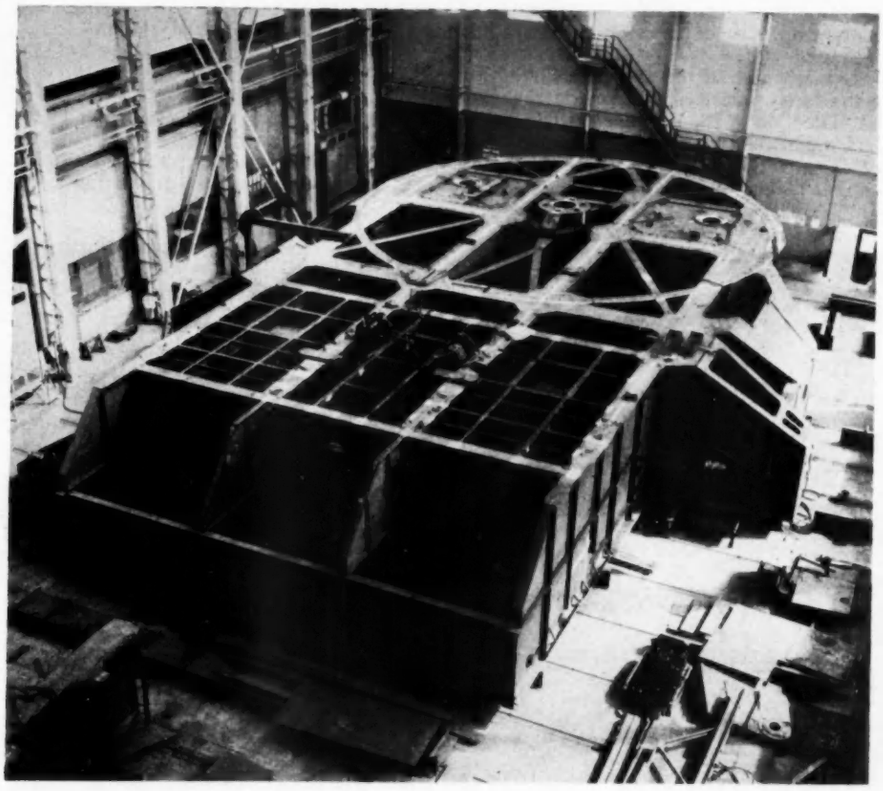
The walking shoes of welded steel plates and sections are each 55ft long by 9ft 6in wide and weigh 58 tons. To provide an effective grip on the ground when the machine is walking, heavy angles are fixed to the shoes at each end. Means are provided to offset the effect in the event of a shoe slipping during the walking movement and tending to rotate about its axis. The angular displacement imparted in such cases is corrected as the load upon the shoe is released by the reaction of a torque control device incorporating rubber bushes.

The machine has a walking speed of 0·11 m.p.h. and this drive is provided by two separate motor-driven units, one on each side of the walking shaft centre line. Each of these units consists of two 225 h.p. motors providing a balanced drive through pinions to a central double helical gear. From the two double helical gears pinion shafts extend parallel to and on each side of the walking shafts, which they drive through straight spur reduction gears. The two main pinion shafts are supported by 2ft 6in long phosphor bronze bearings mounted on the main frame structure and, being situated on diametrically opposite sides of the walking shafts, they provide a balanced drive to ensure that the walking shafts are not subjected to any bending which might otherwise be imparted by heavy tooth loading in the transmission.

The boom, of lattice and girder construction, is triangular in design and is a bolted assembly of high tensile steel sections. To reduce the overall weight of this structure to a minimum the open type flooring platforms, the staircases, handrails, &c., have been made in aluminium alloy. The basic length of the boom is 208ft and either of two extension pieces can be fitted ; one to provide a discharge radius of 260ft and the other for a 230ft discharge radius. A structural tie member and links are used to connect the boom to the " A " frame of the superstructure when the machine is working.

The fairlead comprises two units of similar construction mounted on a single frame built on the upper deck of the superstructure above the main circular girder. In each of these units two vertical and two horizontal cast steel pulleys provide the guiding means for the drag ropes. The 7½in circumference twin hoist and twin drag ropes are of Langs lay " Layset " preformed construction and each has a breaking load of 200 tons.

The sets of machinery used for hoisting and dragging are of similar design and construction except for the grooving of their 5ft 4in rope drums. Each set is self-contained and arranged with its drum on the longitudinal centre line of the superstructure deck. A balanced drive is provided in each set by the use of four 300 b.h.p. at 450 r.p.m. motors arranged in pairs to drive, through flexible couplings, double helical pinions meshing on opposite sides with large diameter central gear wheels giving the first reduction. The shafts of these central helical reduction gears have spur gear pinions machined on their ends meshing with the centrally disposed drum gear wheel. Through this balanced gear drive, a reduction ratio of 39 to 1 is achieved at the drums, which are capable of exerting a maximum pull of 150 tons on the drag and hoist ropes before stalling. Brakes and clutches are not needed for operating purposes on the two main drum drives, but compressed air operated shoe brakes are provided on each of the motors for holding purposes. The drums are grooved for two-rope winding, the rope fastenings being at each end with right and left grooving leading to the centre. Rope speeds up to 428ft per minute are available in operation.



Rotate frame in course of construction. In this view of the underside there can be seen the two heavy-duty transverse girder members built into the frame between the wings for the walking gear

The two driving sets used to rotate the dragline on its base are situated one on each side at the front of the lower deck of the superstructure. Each of these self-contained sets incorporates a vertical shaft 225 h.p., d.c. motor driving through helical and spur reduction gears the shaft of the main pinion meshing with the rotate rack on the base structure. The reduction ratio of 775 to 1 of the drive gives the superstructure a no-load speed of 1·225 r.p.m.

For boom raising and lowering purposes a winch has been installed on the machinery deck towards the front of the superstructure. When required the 6½in circumference rope from the twin drums of this winch are coupled to the end of the link connecting the apex of the boom to the top of the " A " frame. The winch drums are driven through a common shaft and reduction gearing by a 50 h.p., 995 r.p.m. a.c. induction motor.

A " Stacreep " brake is used to control the winch speed during boom raising and lowering operations and for safety reasons a solenoid-operated shoe brake is fitted on an extension to the motor shaft. To facilitate the work involved in replacing the hoist and drag ropes when necessary, a special winch has been installed at the rear of the hoist drum. The controls of this twin-drum 1-ton winch are grouped on a platform behind the drums where the operator has a clear view of the work in progress during rope replacement.

The machinery house has an angle framework covered with overlapping flanged sheet steel and, as in previous large draglines built by the company, operator's cabins extending forward from each of the front corners of the house give a clear unobstructed view of the working area. Dual controls in the cabins enable the operator to work the machine from either side in accordance with the direction of the face along which it is operating.

In a machine of this size accessibility for maintenance and means of speedy changing and handling of the equipment when necessary are of the utmost importance and particular attention is given to these factors in design. An advantage to this end is the fact that all of the motors used in the hoist and drag drives and those used in the walk and swing motions are interchangeable as well as much of the other equipment. This enables a minimum number of spares to be maintained in stock for service replacements. A further advantage in the new machine is that the overhead crane service installed can work more effectively over the full length of the machinery house now the bridge girder is no longer used in the superstructure. To facilitate and speed repairs when necessary a well-equipped fitter's bench is provided and a 440V, 200A continuous or 300A intermittent hand-welding set installed. A crane gantry along the length of the house carries an overhead travelling crane with two 10-ton crabs controlled from an underslung operator's cabin on one end from which a clear view of all parts of the deck is given. Extensions of the gantry are cantilevered 14ft beyond the rear of the machinery house and large doors provide ease of access when handling loads. Pulley blocks of 5 tons capacity are provided on overhead runways at the front of the superstructure for handling the rotate units and the fairlead equipment when necessary.

An effective ventilating system has been installed to provide an adequate supply of clean cooling air for the electrical equipment and maintain the pressure in the machinery house slightly above atmospheric to prevent the ingress of dust. For this purpose a bank of large filter panels has been installed along the lower inclined rear end of the superstructure base. Air drawn in through these panels by fans is first circulated through the box compartments in the base structure—a number of which house transformers, switch gear cubicles, &c.—and is then delivered through grills into the machinery house. All of the machinery installed is lubricated by the " Farvel " metered pressure system with the exception of the rotate units which are fitted with the " Denco " system.

Electrical Equipment

In general the electrical equipment of the " W1800 " follows closely that of the " W1400 " machines described in our issue of November 9, 1951, and the majority was supplied by Associated Electrical Industries, Ltd. Power at 6600V brought to the machine by a trailing cable is taken through slipring collectors to the main h.t. cubicles on the revolving superstructure. These cubicles contain starting equipment for the two main generator sets and power and lighting transformer isolators. Two duplicate main motor generator sets, installed across the tail end of the machinery deck, are each mounted on a welded steel baseplate supported on resilient mountings at eight points. Each of these sets is driven by a 1200kVA, 1000 r.p.m., 6600V synchronous motor, and incorporates a d.c. 550kW, 550V compound wound compensated generator supplying two of the four hoist motors; a similar generator supplies two of the four drag or alternatively two of the four walk motors, and a d.c., 200kW, 275V compound generator supplies one of the two swing motors. In each set, the rotating portion is supported on five pedestal-mounted, ring-lubricated, journal bearings, the pedestal at one end of the set incorporating a thrust bearing. The individual shafts of the four machines in a set are connected by solid couplings having shallow spigots to enable any one machine to be removed without disturbing the remainder.

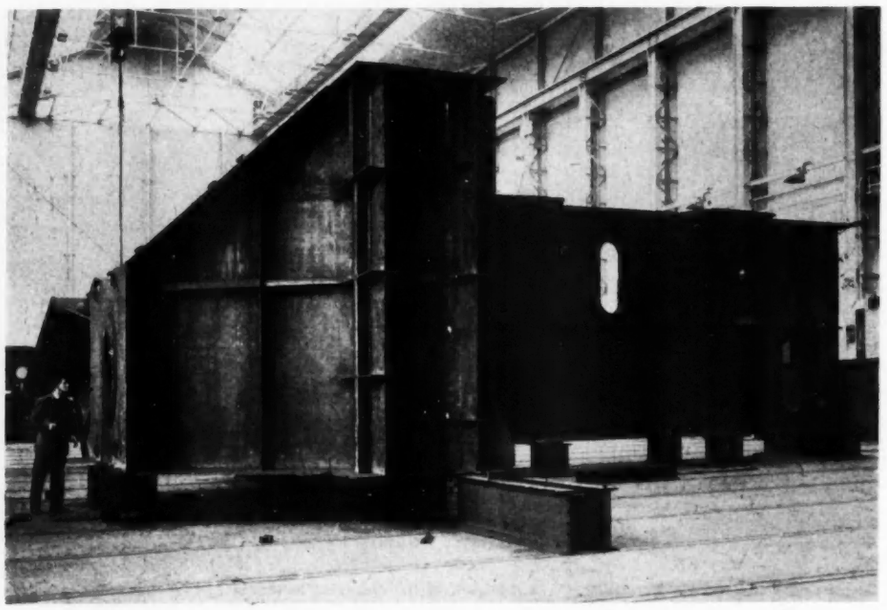
The synchronous motors are auto-transformer started. A single hand-operated oil circuit breaker switches the supply to the motor which is either at tap voltage from the auto-transformer in start, or line voltage direct in run. An air break rotary switch operated from the circuit breaker handle effects the changeover of connections from start to run while the circuit breaker is momentarily open. The synchronous motor fields are supplied from an amplidyne-excited exciter, mounted on a 95 h.p., a.c., induction motor-driven motor generator set. A d.c. generator is also incorporated in this set for supplying the main motion motor and generator fields, &c. Automatic or hand control of the synchronous motor power factor is provided. The excitation is adjusted by the amplidyne to maintain any desired value from unity to 0·8 leading irrespective of load conditions when set for automatic control. An amplidyne set driven by a 95 h.p., a.c. induction motor mounts three amplidyne generators for exciting the separate fields of the hoist, swing and drag/walk generators.

The main motion motors, four each on the hoist, drag and walk and two on the swing operate in tandem, two of each of the four being connected in series across a generator and one swing motor connected to each swing generator. The drag or walk motors are connected to the drag/walk generators via a motor-operated off-load changeover switch, depending upon which motion is required. The separately-excited fields of these motors are fed from a d.c., 125V generator on the exciter set and field weakening is provided to increase the speed range. These motors are individually blown by frame mounted fans.

The control consoles in each of the two cabins around the built-in drivers' seats contain hand levers for the hoist and drag/walk motions and pedals for swinging ; the levers and pedals operating master controllers are situated behind the seats. Mounted on the console arms are pistol grip switches controlling motion parking brakes and the drag/walk changeover switch. Indicating lights show which console is selected for working, lubrication services, &c. whilst conviently situated toggle switches control boom floodlights, &c.

Power supplies at 440V 3-ph. for the amplidyne and exciter set driving motors, blowers, fans, heaters, pumps, &c., are supplied via distribution boards, panels, &c., from a 200kVA, 6600V/440V power transformer. Lighting for the machinery house and the boom floodlights is obtained from another smaller transformer. In the event of the supply being isolated from the machine an emergency battery supply giving light at strategic places is available. All control equipment for amplidynes, d.c. circuits, &c., is contained in steel cubicles, and these cubicles, together with all rotating machinery incorporate anti-condensation heaters which are automatically switched on when the main motor generator sets are shut down.

Another " W1800 " walking dragline at present under construction at the works of Ransomes and Rapier, Ltd., is for Stewart and Lloyds, Ltd., and a third machine for the United Steel Companies, Ltd., is nearing the final stages of erection at Roxby, near Scunthorpe.



Walking wing and one of the heavy transverse girders being assembled at the maker's works

Institution of Locomotive Engineers

In his presidential address to the Institution of Locomotive Engineers in London on Tuesday, September 26, Mr. J. F. Harrison first touched upon some of the events in the locomotive world of the past forty years which he considered had a profound effect upon the motive power of the former L.N.E.R. He then went on to examine the physical progress made in introducing new forms of motive power; to give examples of the improvements in revenue earning services; and to indicate some important development work. For this article we have abstracted passages dealing with motive power from the second part of Mr. Harrison's address.

WHEN the British Transport Commission announced their Modernisation Plan in 1954, the steam locomotive fleet in Great Britain numbered 18,420. The standard of maintenance had reached an extremely high level, no more than 4·5 per cent being "under and awaiting workshop repair," and no more than 9·5 per cent "in shed under repair," giving an overall availability of 86 per cent. The coaching vehicle fleet, excluding some 16,000 non-passenger carrying units, numbered some 42,000, including a modest 4700 electric and diesel multiple unit vehicles, with an "under and awaiting repair" figure of some 8·4 per cent. The wagon fleet numbered 1,124,710, including 179,788 fitted and/or piped vehicles, with an "under and awaiting repair" figure of 6·5 per cent. As you know, the Modernisation Plan stated—and here I quote briefly—that steam would be replaced by diesel or electric traction; loco-hauled trains in rural and urban areas would be superseded by diesel-driven railcars; new and better coaching stock vehicles; a substantial reduction in the wagon fleet, and an extension and rapid modernisation of this fleet by such means as vacuum brake fitting, automatic couplers. Let us see what the position is to-day; what has been achieved some seven years later.

The first of the railcar units suffered a number of teething troubles, which one may now look back upon with some wonder, and question why such troubles were ever necessary. The reasons, in general, are, however, quite simple. The mechanical equipment and electrical control equipment of the diesel mechanical cars was based upon similar kinds of vehicle equipment previously used on the roads of this country with great success, which, however, had not been subjected to the vibration and rough and tumble work of a vehicle having steel wheels and running on steel rails. Engines of these railcars are now running 90,000 to 100,000 miles between top overhauls and 180,000 to 200,000 miles between general overhaul. Control gear has been improved and brought up to a standard more in keeping with the standards adopted many years ago for electric traction services.

It is always difficult to compare figures when one is in the middle of a plan as large as the British Railways' Modernisation Plan, but by careful sifting of the facts and segregating performance into like for like pockets, one finds to-day that the following picture is developing.

For comparable duties steam locomotives performing express passenger work are averaging 170 miles per calendar day with an average casualty rate of one per 17,000 miles, whereas working similar express passenger services, diesel locomotives of comparable power are averaging 300 miles per day with a casualty rate varying according to Region as between one in 12,000 and one in 22,000 miles. The miles per day mentioned can be compared with the steam locomotive figures previously given.

One of the main sources of failure with diesel locomotives is the steam heating apparatus, and this accounts for a large proportion of the casualties, so much so that if the above-mentioned figures were adjusted to eliminate steam heating failures, then the diesel locomotives would be averaging a varying casualty rate of one per 15,000 to one per 26,500 miles.

As a confirmation of the effect of the steam heating apparatus failures, the satisfactory standard Type 1 diesel locomotives, which are not fitted with steam heating boilers, employed on freight transfer and shunting duties with some main line working, are averaging a casualty rate similar to steam, something like one per 70,000 miles, or one casualty per locomotive every 2½ to 3 years.

The present casualty rate figures are not particularly good, but what is satisfactory is that each month they show an improvement as teething troubles are eliminated. One looks forward with some degree of confidence to very much better figures in the future, and this will be particularly noticeable when areas become dieselised completely, and diesel locomotives diagrammed to undertake the duties they are capable of undertaking compared with steam.

The teething troubles that have been experienced divide themselves into four main equal parts: (*a*) steam heating boilers; (*b*) control gear; (*c*) engine equipment (blowers, pipes, &c.); (*d*) miscellaneous.

Originally it was felt that the likely sources of trouble would be the engines themselves, transmissions, pipes, &c. Engines have been pleasantly free from trouble of the kinds we feared, although each and every one has suffered initially from some curable "digestive" difficulty. Electrical transmissions have given, in general, a satisfactory performance. What troubles there have been are, in my view, due to manufacturing deficiencies rather than design problems. Superchargers, however, have been a constant source of trouble with some engines, and control gear is only now being produced in a satisfactory and robust manner. The steam heating generator with all the numerous components necessary to provide automatic control to fuel and water, &c., has given endless trouble, but I am pleased to say that the steps taken by manufacturers to improve the standard of equipment, and by ourselves, to ensure the adherence to a rigid schedule of maintenance, have already shown most encouraging improvement.

When the products of the original design of Type 4 main line diesel locomotives made their appearance as $1C_0$–C_01 locomotives, British Railways were criticised on the grounds that the design gave a very poor power/weight ratio compared with other designs from European countries. What was not known by the critics at that time was the reasoning behind this particular wheel arrangement. It arose as a consequence of a need to reduce the ratio of axle weight to wheel diameter in feet, or P/D, to a figure not exceeding 4·5. This ratio was fixed by the Chief Civil Engineer as a wise move to control excessive rail breakage, as such a condition was thought, at that time, to be one of the main contributory causes of fractured rails.

Since 1957 much thought has been given to this problem, and locomotive designers have also been helped in reducing overall weight by the increase of power to weight of the diesel engine and transmissions, so that the present standard Type 4 main line locomotive is being built as a C_0–C_0 of 114 tons compared with 136 tons of the original $1C_0$–C_01 giving a horsepower/weight ratio of twenty-four compared with seventeen, and a much improved route availability, as the C_0–C_0 is able to negotiate 10 chain vertical curves compared with a minimum of 17 chain vertical curves for the $1C_0$–C_01—a matter of some great importance where marshalling yards have no engine escape road.

The latest design of Type 1 locomotive will perform a fair amount of trip working, yard to yard, as well as shunting duties, and its advantages will be appreciated, particularly as some will be fitted with steam heating boilers for preheating empty coaching stock when being worked into stations.

The table below shows, as a matter of interest, particulars of a Type 2 diesel electric locomotive uplifted in horsepower to qualifiy as Type 3, alongside a Type 3 diesel electric and a Type 3 diesel hydraulic, and shows what can be done to improve the horsepower/weight ratio by using four axles instead of six, providing always the stock to be hauled is suitably braked.

Comparison of Type 3 Diesel Locomotives

	Brush uprated	English Electric	"Hymek" Beyer Peacock
Transmission type	Electric	Electric	Hydraulic
Wheel arrangement	A1A–A1A	C_0–C_0	B–B
Engine horsepower	1,600	1,750	1,700
Maximum tractive effort, lb	42,000	55,500	49,700
Continuous tractive effort, lb	21,240	35,000	33,950
Locomotive weight in w/o tons	104	102	74
Length over buffers	56ft 9in	61ft 6in	51ft 8½in

This brief outline of our new locomotive types would not be complete if I did not mention the 1500 h.p./600 h.p. electro-diesel locomotive of B_0–B_0 wheel arrangement now in the course of construction at Eastleigh under Mr. W. J. A. Sykes's direction. This locomotive to me seems to be a "winner." One can foresee a great future for it, not only on the Southern Region, but also for a.c. overhead electrified lines, and will, I hope, be available in plenty of time to meet the obvious need of feeding the main electrified trunk lines from lightly loaded lines (i.e lines which could never justify electrification in their own merit), and also to provide through freight services during the night hours when current is switched off for maintenance purposes over intermittent short sections.

The new forms of motive power have necessitated a considerable change in the character of our main locomotive works, and by a little inexpensive re-arrangement, the main factories have been adapted generally to cope with the new form of "repairs" whilst at the same time retaining facilities to deal with the still very large number of steam locomotives which have to be kept going to the same standard of efficiency as in the past.

Nevertheless, substantial economies in maintenance capacity have already been achieved in all forms of rolling stock maintenance expenditure. Examples of reduction

of maintenance costs are as follows:

Diesel multiple unit four-car trains compared with steam-hauled four-car trains cost 1s. 10d. per train mile compared with 2s. 8d. per train mile when steam hauled (these figures in both cases cover not only mechanical equipment but also coaching stock costs). (34 per cent reduction.)

Diesel main line locomotive-hauled trains, average fifteen coaches, show a train mile cost of 1s. 6d. compared with similar fifteen-coach steam hauled train cost of 2s. 5d. per train mile, excluding coaching portion, or a reduction of 38 per cent.

Ultimately one can think in terms of reducing maintenance expenditure on locomotives by a figure which would conform with the actual reduction in unit numbers. It is possible this may be an over estimation, but the general trend of miles per top overhaul and miles per general repair of the best type of diesel locomotives leads one to think this ratio is about correct.

To-day our main works are repairing some 1800 railcar engines and transmissions per annum, and the figures I gave in my paper to the Institution of Civil Engineers regarding the probable main line diesel locomotive miles to top overhaul and miles to general repair appear to be working out as forecast, this indicating the load we shall have to undertake in progressively increasing amounts during the forthcoming years.

The general effect of the last seven years of modernising our equipment, and this is only partially complete as you will realise, has resulted in a reduction of our maintenance staff, both main works and outstations, by some 14 per cent, and our maintenance expenditure to outside sources by as much as a further 36 per cent. This coupled with the increase in our passenger revenue, as detailed earlier in this paper, clearly shows that the first crop is a good crop, perhaps better than was expected from new trees only planted five years ago, and not yet fully bearing; and gives great hope and encouragement to everyone in our business.

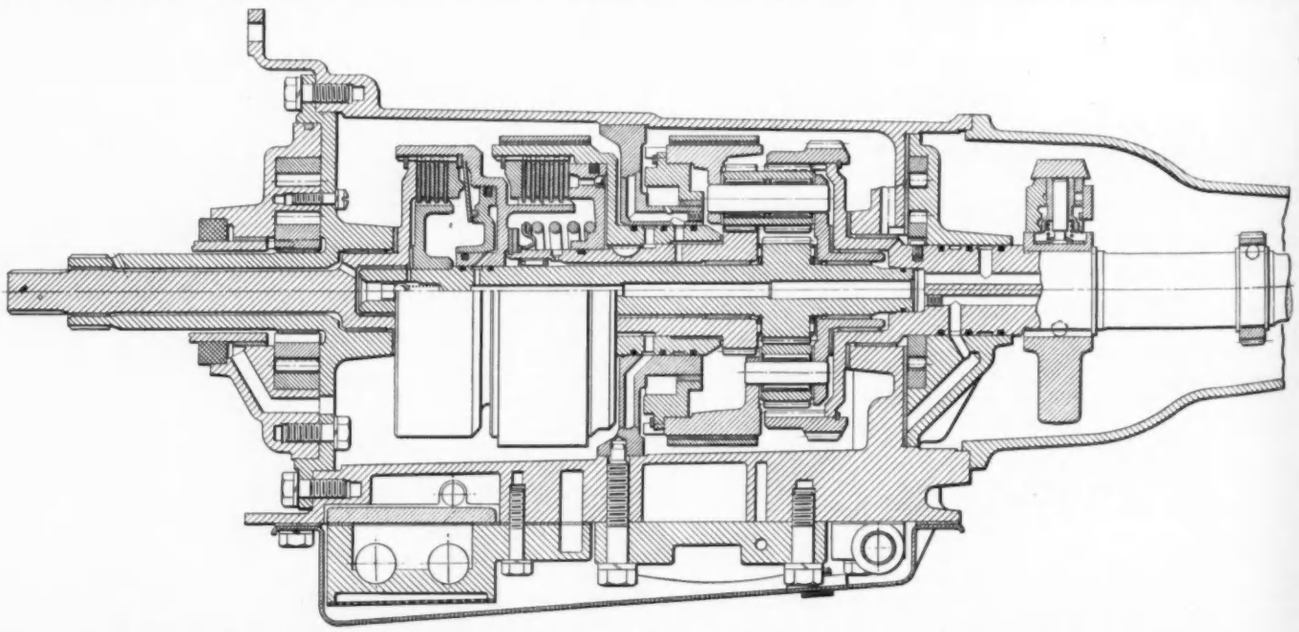
Compact Automatic Transmission

A transmission based on a design well established in the United States, using a single epicyclic with two sun wheels and meshing long and short pinions to give three forward and one reverse gears, has now been scaled down and considerably lightened for use in vehicles of less adequate power/weight ratio.

IT being apparent that a large proportion of European cars is equipped with three-pedal control systems having no pretension to being designed to suit the driver's characteristics, Borg-Warner, Ltd., in concert with the Warner Gear Division of the parent firm, the Borg-Warner Corporation, made a survey to discover the requirements of a large number of designers. It transpired that there was a major demand for a transmission for 1½ to 2½ litre engines, and that in exchange for fully automatic control motor manufacturers were prepared to accept a performance no better than, or even perceptibly inferior to, that with a manually operated clutch and gearbox. The transmission which Borg-Warner has been manufacturing in this country hitherto was originally designed to match highly refined engines developed to operate with three-speed gearboxes, and consequently would need to make excessive use of the reduction ratios if coupled to one of the four-cylinder engines popular in Europe. However, some years ago the parent firm developed a transmission which drives exclusively through a torque converter, and can therefore be matched with an engine that is not smooth at the lower end of the speed range. The possession of a transmission in being allowed prototypes of what was virtually a scaled-down "Fordomatic" transmission to be made available with little delay, and it was found that the design was as suitable for small engines as for large. The close relationship between the new design and the existing Ford equipment meant not only that understanding of the transmission was already virtually world-wide (although, it should here be emphasised, mechanical interchangeability is absent) but also that Borg-Warner could safely guarantee the performance of the transmission in service, and hence it proved possible to secure substantial orders for the new unit, the Model 35, before tooling up to produce it. The detail design is ambitious—for instance, the main casing is a light alloy casting, so that the weight of the complete assembly is less than that of some of the four-speed manual gearboxes that are in production in Europe—and hence the outlay on production facilities amounted to no less than £4,000,000.

Borg-Warner, Ltd. will manufacture transmissions with two different converters, either 9½in or 11in in diameter; it is interesting to note that no attempt is made to save weight in the converters, as it was found that with a converter of low polar moment a four-cylinder engine was objectionably rough—consequently the converter is made out of substantial steel stampings (with the attendant advantage that accuracy is high and hence the consistency of the hydraulic characteristics is good), while the 9½in version includes an inertia ring.

The gearbox proper, it will be recalled, is distinguished by deriving three forward and one reverse ratios from a single "simple" (in the sense that it has only one planet carrier and one annulus) epicyclic cluster. When this transmission was designed, Ford passenger cars had engines that were adequate for their duties with three-speed mechanical gearboxes, and so the original "Fordomatic" drive started in the second lowest ratio, the first being engaged only if "Low" was selected. It became preferable, however, to start in the lowest ratio, at least in "D1" (high performance), which implied that the transmission would normally change down into this ratio as the car came to rest. Any sudden abstraction of energy is particularly noticeable when the vehicle is moving slowly, and so the drum brake that arrests the planet carrier in first was supplemented by a sprag clutch, the effect being that in first the car can free-wheel unless the brake band is tightened. The new transmission has only two forward modes, "L" and "D," and only in the former, "lock-up," is the brake applied.

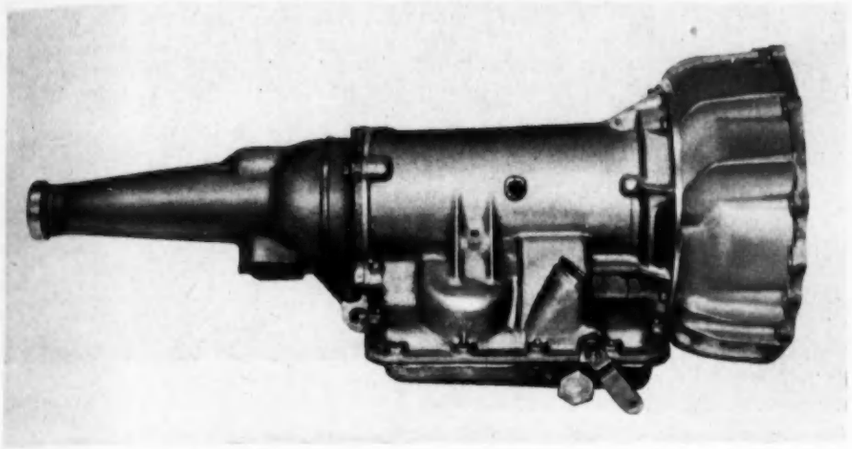


Section through gearbox; notice the sprag clutch within the rear brake drum, and the diaphragm spring loading the front clutch

While the gearing is in principle that of the "Fordomatic," however, it was found that with the light alloy casing gear noise was more apparent and so a hunting tooth was introduced; this caused the forward ratios to close up by 2 per cent to 1·45 and 2·39, and the reverse ratio to rise from 2·00 to 2·09.

The control system has been considerably simplified for the European transmission; in particular, the system gives no protection against abuse, as by overspeeding the engine in "L," engaging a range when moving in the opposite direction, or selecting "P"ark when in motion. The selector works in a quadrant marked "L–D–N–R–P," and a spring-loaded catch isolates the "R–P" end; "R" has been moved from its usual position beyond "L," it being explained that the occasion for reversing is most often that the car has been "P"arked in a garage. If "L" is selected when second or third gear is in action, second is held until a rather low (depending on the throttle setting) speed is reached and first is then engaged. The duty of the hydraulic control system is, in principle, simple. "N"eutral, "P"ark and "R"everse require of course unique connections, with respectively nothing, nothing, and the rear clutch and the rear band supplied with pressure. When either forward range is selected, the front clutch is closed (notice that it is energised through a diaphragm spring), and changes involve the 1→2 shift valve supplying the "apply" side of the servo for the front brake, and the 2→3 valve supplying the "release" side of the front brake servo and the rear clutch. Movement of the shift valves is effected by balancing governor pressure, which depends upon road speed, against a pressure modulated by the throttle. Some modification of the circuit with speed, namely introducing restrictions by means of servos, is necessary to render the changes at light throttle openings acceptable.

An interesting departure from the larger transmission in the interests of lower cost is that the mechanism generating the required function of throttle travel is not part of the throttle control linkage, but takes the form of a cam within the transmission; the cam is moved by a Bowden cable, the stranded inner element being wrapped round it in the manner of the commonplace twist-grip. The control unit itself, an intricate and closely toleranced component, is common to all transmissions; to match the transmission to different engines and duties, the designer will alter the characteristics of the governor, the number of sintered metal plates in the clutches, and the sizes of the servo motors applying the brakes. The governors will normally be set to change up about 200 r.p.m. below peak power, it having been found that engines developed for use with manual transmissions have inadequate endurance to allow sustained running at peak power. As indicated earlier in the text and in the drawing, the converter housing and rear extension are made separate in order to facilitate installation in different cars; the one fundamental difference between components for different applications is that whereas Borg-Warner normally cuts female threads directly in light alloy and specifies torque wrench figures, Ford Motor Company, Ltd. requires that "Helicoil" inserts shall be used on any transmission that they may acquire.



Transmission complete with converter housing and rear extension; above the transverse selector shaft is the threaded opening for the cable to the throttle linkage

We have been afforded the opportunity to drive one of these transmissions in a car that could not be said to flatter it, an extremely un-aerodynamic 4/6 seater saloon with a 1½ litre cast iron engine with push-rod valve gear. "Hot" shifts were obtrusive when the vehicle was stationary and while the transmission was cold, but normally changes were hard to detect. The relatively small multiplication built into the converter resulted in only slight changes of engine speed with load, giving a sluggish over-geared impression accentuated by pinking, but over a wide extent of the speed range it was possible to command higher performance by flicking the selector down to "L"ock-up and obtaining second gear. When descending steep hills in "L," a satisfying trick is to kick down momentarily when the speed has dropped below 20 m.p.h.; a second or so later first gear will engage, thus allowing the left-hand pedal to be released. Since this transmission, in contrast to the automatic overdrive, (THE ENGINEER, Sept. 23, 1955) uses an hydraulic instead of an electric control system (because the demand for reliability is much intensified if the vehicle cannot be used with the automatic control unserviceable) any response involving a change of ratio is necessary deliberate, so that even a differentiating device on the accelerator control would not avoid the need for enhanced anticipation. It is anticipated by the manufacturers that the performance in a full-throttle acceleration will prove rather better than with a clutch-and-gearbox transmission, the maximum speed be slightly less, the fuel economy in open road conditions be also slightly less, and the consumption in traffic driving be improved markedly, due to the use of a higher first gear with a free-wheel. It is also claimed that a reduction in the cost of transmission maintenance will be effected, not only because automatic transmissions are less severe upon propeller shafts, final drives, and axle shafts, but also because the cost of servicing the gearbox itself is reduced; the only rectifications anticipated are adjustment of the control linkages and the band brakes, and no oil changes are scheduled (although adjusting the front brake involves removing the sump).

"Bulb" Turbines for the Awe Barrage

THE North of Scotland Hydro-Electric Board has placed a contract with the Armfield Hydraulic Engineering Company, Ltd., for the supply and erection of two "bulb" turbo-generator sets for the Awe barrage in Argyllshire. The barrage is near the outlet of Loch Awe and will divert water into a tunnel leading to Inverawe power station. Loch Awe will also constitute the lower reservoir of the Cruachan pumped storage section of the scheme.

The two "bulb" sets will each be designed to develop 695 b.h.p. at a net head of 22·5ft. The main contractor named above is supplying "bulb" turbines manufactured by Ets. Neyrpic, Grenoble, driving induction generators made by Alsthom of Belfort. The "bulb" sets will be similar to machines already supplied by Ets. Neyrpic for various installations in France, and they are due to be commissioned in August, 1962. Work on the barrage is already well advanced.

The electrical and mechanical engineering consultants for the Cruachan and Inverawe sections of the Awe scheme are Messrs. Merz and McLellan; the civil consulting engineers are Messrs. James Williamson and Partners. The scheme was briefly described in THE ENGINEER of July 26, 1957, and articles describing "bulb" turbines have been published in our issues of October 29, 1954, January 27 and February 3, 1961. Last month it was announced (see THE ENGINEER, August 11, page 241) that high-head reversible pump/turbines will be installed on the Cruachan section of the scheme.

Industrial Accidents

MR. JOHN HARE, the Minister of Labour, attended the press conference held earlier this week at which Mr. T. W. McCullough, H.M. Chief Inspector of Factories, introduced his annual report for 1960. The report records that for the second year in succession there had been a rise in the number of accidents, and that the total of 190,226 was 6 per cent above that for 1959 and the highest for ten years. Of these, 675 were fatal, compared with 598 in 1959. The rise in accidents to young persons was particularly serious, the Chief Inspector states in the report, and the increasing numbers of young persons coming into industry presented the greatest challenge of all, since they must be trained in safe working practices from the very beginning.

Addressing the conference, Mr. Hare said that he had attended the press conference this year because of his very serious concern at the continuing rise in industrial accidents. Apart from the suffering, he added, accidents on this scale represented a wholly indefensible waste, and industry simply could not afford these continuing losses. Mr. Hare went on to say that following discussions with the British Employers' Confederation, his Department was writing to the employers' associations in certain sectors of industry where safety was a serious problem. The Ministry wishes to discuss with them, he said, what more can be done to tackle the problem.

The annual report of the Chief Inspector of Factories on Industrial Health was also published this week.

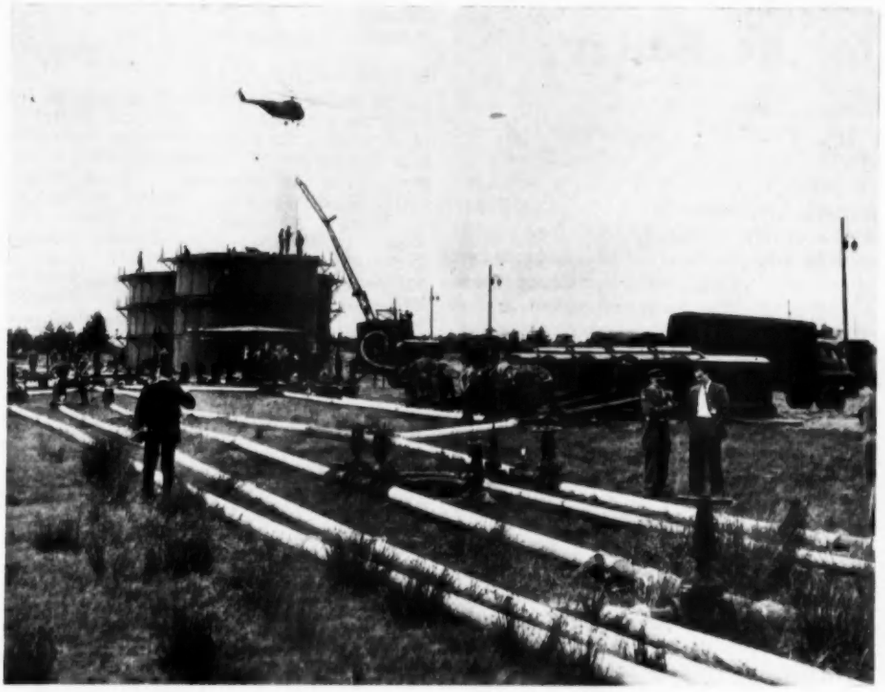
Petroleum Supply in the Field

For this and the preceding two weeks there has been proceeding at No. 1 Petroleum Reserve Depot, R.A.S.C., at West Moors in Dorset, Exercise "Go-Devil," intended to practise new methods of supplying and storing petrol, oil and lubricants in the field. Large quantities of fuel are involved; for example, one armoured regiment needs 10,000 gallons for a move of 50 miles. For this reason, while collapsible fabric tanks and "Dracones" are envisaged for use in the initial stages of a build-up, full scale supply involves pipe-lines and bulk storage. In order to effect large reductions in the labour of construction, the pipelines are assembled from aluminium pipes, 4in or 6in diameter, although the light alloy pipes are initially much more costly. RIGHT, a bundle of 6in pipes are being lifted by a Westland "Whirlwind" (S-55) helicopter for carriage over rough ground; notice that the pipes are lifted from one end, although this involves threading a strap through two of the pipes, since at high speed the suspended load swings wildly and pipes carried at the middle have threatened rotor blades. The ground crew are in communication with the pilot by telephone, and the connection, protected in its fall to the ground by a rubber ball, can be discerned near the bottom of the fuselage.

The light alloy pipes weigh only 80 lb and can, as demonstrated LEFT, be handled by one man. The pipes are joined by "Victaulic" couplings fitting into grooves machined into the pipes near the end, the walls being thickened at the ends to allow this. A special coupling is also available which can be used to join cut lengths of pipe. The "Victaulic" joint is seen being assembled on the RIGHT; the two pipe ends are covered by the rubber joint ring.

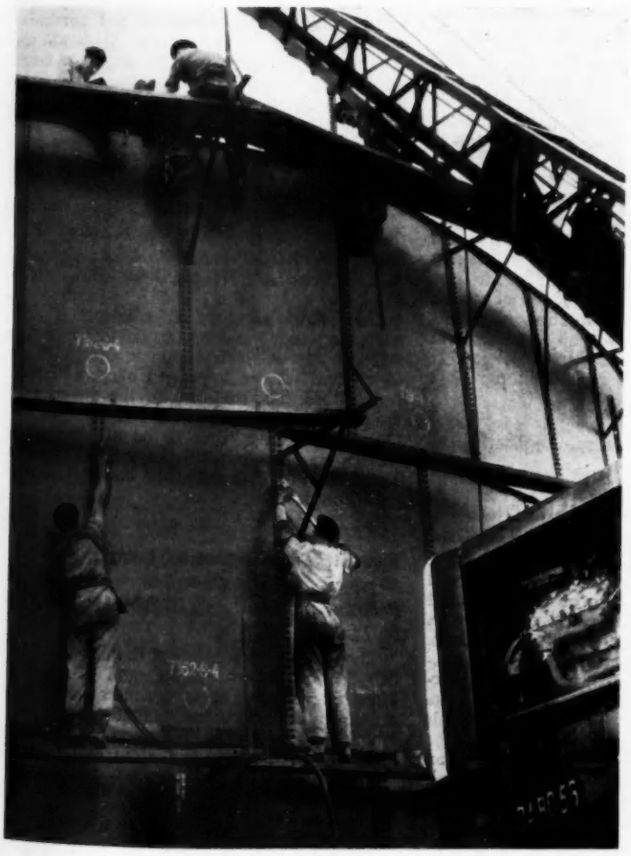
The use of a self-energising joint in which the gasket is loaded by the hydraulic pressure (the rubber ring has a hollow box section, open opposite the ends of the pipes) renders the making of joints rather quick and easy, and also results in much lighter plumbing. It is interesting to note that the joining up of adjacent pipes is the operation determining the time needed to build a pipeline, and the amount of labour that can be deployed is severely limited by the lack of yield along the axis of the coupling, i.e. only one end of a pipe can be coupled at a time. Various techniques for coupling up have been tried, and it has been proved quickest to start two parties at the ends of the pipeline, working inwards, and additional pairs of parties working outwards from intermediate points; thus joints between long lengths of pipes number only half the number of coupling parties.

The pipeline requires large numbers of valves, some of which can be seen RIGHT. The valves in the background are conventional designs used in civilian practice, but in the foreground can be seen two examples of valves evolved in Germany for temporary installations. The use of self-energising seals and of welded instead of cast bodies, and some simplification of the mechanism, has, it will be evident, reduced the size considerably; the new valves can be carried by two men with poles engaging hooks on the body.



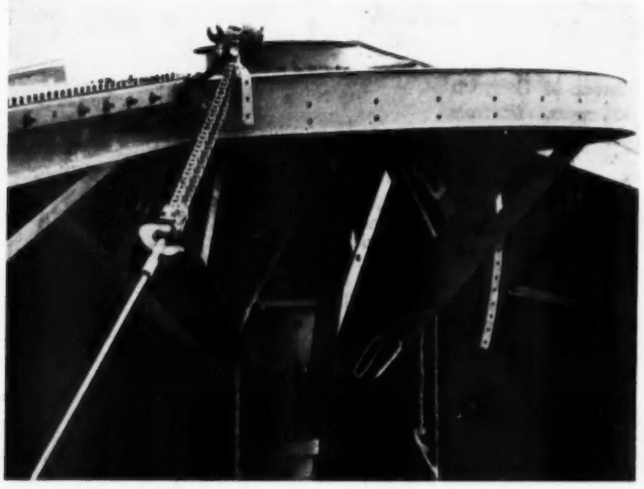
On the RIGHT can be seen the tank farm and pumping station as it looked after eight day's work. The aluminium pipeline will stand a working pressure of 600 lb per square inch, and this is generated by a series of pumps each running at a differential of 200 lb per square inch, with a fourth pump as a standby ; the pumps are powered by Dorman diesel engines and each set is sled-mounted. In the background can be seen three bolted steel tanks of 17,500, 105,000, and 350,000 gallon capacities, of which the latter is still in course of erection.

BELOW work is seen in progress on the large storage tank ; the third tier of plates having been emplaced, the second tier is being finally tightened, the two men on the scaffolding being equipped with a pneumatic nut-runner (left) and a torque wrench (right). This tank has about 35,000 bolts and nuts in its construction ; black bolts are adequate, since their principal function is to load the synthetic rubber gaskets, and the square heads are held by channels along the lines of holes. The large and powerful crane employed is a Coles crane on a six-wheeled A.E.C. chassis and having its own Ford V-8 twenty-one-stud engine.



The tank is, when incomplete, relatively weak and flexible, and it is rendered circular only when the roof is added. Inside the tank there is a king post which supports the centre of the roof ; BELOW half of the roof panels have been placed, but the internal structure can still be seen.

While the operation of a petroleum installation is a Royal Army Service Corps responsibility, it is erected by Royal Engineers. The large and critical task of planning and designing a project such as this is handled by R.E. Specialist Teams (including, in this case, one belonging to the Army Emergency Reserve, and drawn largely from civilian oil companies) ; these teams also provide certain specialist tradesmen as well as supervising the troops carrying out the construction. The helicopter and its crew, including those on the ground, belong to the Royal Air Force.



Letter to the Editor

SAFETY

SIR,—Your stimulating article on the above subject, in your issue dated September 18, raises the question of why we still have so many accidents with so much knowledge of safe working available. With long experience in these matters I would suggest that causes are outside the province of those actively and most nearly employed in this work. Small firms, which employ about half the population of engineering workers, and where much improvisation must be done, undoubtedly contribute largely to our national accident records, and perhaps there is too much tolerance allowed them by H.M. Inspectorate. Accident risks are no part of the bargain for employment. The building industry is now within the scope of the Chief Inspector of Factories, and it will take a decade or two to bring it into line with all requirements.

Regarding large well-organised engineering firms, do not some accidents arise from American methods of management, aided and abetted by our taxation system, in encouraging larger staffs than are necessary ? The workshop supervisor just simply cannot be close enough to his men and machines, being otherwise engaged in production paperwork, and seldom making decisions himself. I smiled at your naive suggestion that an employee who disregarded precautions available for his safety should be instantly dismissed. This is good sense, but does not fit into the pattern of joint consultation between management and workers. Accident rates are a reflection of workshop discipline.

To make organised safety more effective Safety Officers primarily must be experienced engineers, and there must be more of them. Their work, whilst being purely advisory, must also be held in higher esteem, which means a higher status for these officers.

C. J. POTTS, A.M.I.Mech.E.

Kenilworth,
September 18, 1961.

Books just published

Carbon-14 Compounds
128 *pages. Illustrated.*
Publisher : Butterworths and Co., (Publishers), Ltd. 1961. *Price* 30*s.*
by JOHN R. CATCH.

This book is a guide to the literature and the use of Carbon–14 compounds. The author, who works at the Radiochemical Centre of the U.K.A.E.A., has outlined the developments and uses of these isotopes as a general guide to scientists who work with them. The introduction gives a very comprehensive bibliography of carbon isotopes, and the chapters on production, chemical synthesis, biological labelling methods, peculiar features, analysis, measurement and handling precautions are each well supplied with references for further reading. An appendix of new material appearing since the preparation of the book and a detailed index complete this volume.

Mathematical Theory of Linear Systems
260 *pages.*
Publisher : Chapman and Hall, Ltd. 1961. *Price* 50*s.*
by B. M. BROWN, M.A.

The author has attempted to present the basic mathematical theory of linear control in its most elementary form, in order to give the practising engineer a complete account of the mathematical methods needed in solving synthesis and analysis problems. Chapters are included on Fourier series and integrals, Fourier and Laplace transforms, step and impulse functions, linear systems, statistical methods, design of optimum systems and sampling and interpolation systems. Exercises and appendices are included, and an excellent contents list supplements a somewhat scanty index.

Toughness and Brittleness of Metals
108 *pages. Illustrated.*
Published for the Institution of Metallurgists by Iliffe Books, Ltd. 1961. *Price* 27*s.* 6*d.*

This book is a reprint of the four papers given at the annual refresher course of the Institution of Metallurgists in 1960. The contents of this volume include," Definition and Significance of Toughness and Brittleness in Metals " by N. J. Petch, B.Sc., Ph.D., D.Met., F.I.M.; " Engineering Aspects of Toughness and Brittleness in Metals " by G. M. Boyd, O.B.E., M.R.I.N.A., A.M.I.Struct.E., N.M.E.C. Inst., M.Inst.W.; " Effect of Environment on Embrittlement in Metals " by E. A. G. Liddiard, M.A., F.I.M. and " Metallurgical Aspects of Ductility and Brittleness in Metals and Alloys " by H. M. Finniston, B.Sc., Ph.D., F.I.M. These contributors are leading authorities in this particular field, and each has attempted to survey the present state of knowledge. Each paper has its own short bibliography, and an index covering all four papers in the volume is included.

Handbook of Numerical Methods for the Solution of Algebraic and Transcendental Equations
195 *pages* *Price* 40*s.*
Publisher : Pergamon Press. 1961.
by V. L. ZAGUSKIN. Translated by G. O. Harding, D.Phil.

This is a translation of the Russian volume which was published by Fizmatgiz, Moscow, in 1960. The book is intended as a practical aid to engineers who use mathematical methods in the solution of technical problems. There is an introductory chapter of initial information about polynomials and transcendental functions, followed by chapters on operations with approximate numbers ; methods for the approximate determination of roots ; methods of making more accurate roots already found ; solution of equations of low orders and extraction of roots ; and a final chapter on the solution of simultaneous equations. There is a bibliography and an index. The book is printed by non-letterpress methods and reproduced by photo-lithography.

Frequency Modulation Theory, Application to Microwave Links
488 *pages. Illustrations. Diagrams.*
Publisher : Pergamon Press. 1961. *Price* 100*s.*
by JACQUES FAGOT and PHILIPPE MAGNE

The book is intended both for the microwave link specialist and for the non-specialist who will find an exposition of general problems connected with this modulation process. Part 1 discusses the properties of propagation of radio waves, Part 2 the general problems of frequency modulation and Part 3 deals with propagation distortion. Part 4 considers in detail the requisite conditions for meeting the international standards (CCIF and CCIR) and is concerned with the complete problem of telephony and television transmissions over radio links. Part 5 deals with applied techniques and equipment. There is a subject index and a bibliography.

Handbook of Mechanical Wear, Wear, Frettage, Pitting, Cavitation, Corrosion
469 *pages. Illustrations. Diagrams. Price* 140*s.*
Publisher : The University of Michigan Press, Ann Arbor, U.S.A. 1961.
Edited by CHARLES LIPSON and L. V. COLWELL.

The volume consists of seventeen papers presented at the College of Engineering of the University of Michigan as part of an intensive course on various aspects of wear, including causes and remedies. The papers are grouped into sections on fundamental aspects of wear ; pitting, scoring and spalling ; corrosion ; abrasion ; wear resistance materials ; and manufacturing processes. There is a summary and bibliographies to each paper.

Electronics : A Bibliographical Guide
411 *pages.*
Publisher : Macdonald and Co. (Publishing), Ltd. 1961. *Price* 65*s.*
by C. K. MOORE and K. J. SPENCER.

The guide is divided into sixty-eight sections. Section 1 lists abstracting, bibliographical and translating services as a guide to means by which any paper may be located. Sections 2 to 68 are classified according to subject and list directly the most important works in each subject published during the years 1945–59. Complete bibliographical details, the total number of references cited, and a brief annotation are given for each entry.

Fourier Transforms and Convolutions for the Experimentalist
120 *pages. Diagrams.*
Publisher : Pergamon Press. 1961. *Price* 30*s.*
by R. C. JENNISON, Ph.D., B.Sc., F.R.A.S.

The aim of this monograph is to make available to the experimentalist a guide to the principles and practical applications of the Fourier transformation. Parallel pictorial and elementary mathematical arguments are used throughout and the treatment includes instructions for qualitative methods of solution. The book is intended for engineers and physicists and emphasises the importance of the Fourier transform and convolution in optics, electronics, aerial design and analogous applications in other fields. There is an index.

Better English for Technical Authors, or Call a Spade a Spade
122 *pages. Illustrations. Price* 14*s.*
Publisher : Leonard Hill (Books), Ltd. 1961.
by T. W. KIRKPATRICK, M.A., Dip.Agric., F.R.E.S. and M. H. BREESE, B.Sc., D.I.C., F.R.E.S.

This short treatise on elements of style, grammar and punctuation developed from a study of the more common errors perpetrated by students at the Imperial College of Tropical Agriculture. The majority of the examples are, therefore, on agriculture or related topics, but the authors have tried to be of assistance to writers on other scientific or technical subjects. There is a brief index and the book is illustrated with line drawings.

First Stages in Engineering Drawing
60 *pages. Diagrams. Price* 5*s.*
Publisher : Edward Arnold (Publishers), Ltd. 1961.
by D. J. HASTINGS.

The author is a lecturer at the County Technical School, Grays, Essex, and the book is intended as an aid to teachers of technical drawing and their students. Pictorial projections are introduced before orthographic projections and all exercises are graded in difficulty as is the introduction of new topics. The book is printed by offset lithography and bound with spiral wire binding.

Variety of Paper Sizes in the U.K.*

By M. H. PHERWANI, B.E. (Hon.), D.I.C., and S. EILON, Ph.D.

Case studies in the consumption of stationery paper revealed a wide variety of products and a pricing policy which does not penalise customers for ordering non-standard or odd sizes. Cost analysis by use of break-even charts is not applicable owing to the difficulty of allocating fixed costs to the various products. The amount of scrap caused by cutting paper rolls to predetermined stationery sizes is suggested as an alternative criterion, and application of linear programming to scheduling of paper sizes is demonstrated. An overall saving to the industry of about 2 per cent of produced material is estimated to be the result if scientific scheduling is adopted.

THE paper industry in the United Kingdom caters for demand in writing and printing paper in a wide range of sizes, and as variety is often associated with wasteful deployment of production resources, it was decided to study the effect of variety in the paper industry by means of several case studies.

The conventional method of analysing variety relies on sales income and profit distribution charts and on profit-volume (or break-even) charts. The former indicates which products are largely responsible for the major portion of the business; the latter is based on the division of production costs into fixed and variable parameters and shows which products are most profitable to produce.

In the paper industry it appears that application of the break-even charts is extremely difficult, first because it is often impossible to allocate fixed costs to specific products and secondly because the price of paper is determined by its weight, so that the profit margin is the same for any given quality of paper and is unaffected by the paper size.

The investigation reported here endeavours to answer two problems :

(*a*) Who suffers the brunt of diversification?

(*b*) What other criterion (in the absence of break-even charts) should be employed to study the effectiveness of the plant?

Present Position of Paper Sizes

The first British Standard B.S. 730 on paper sizes (writing and printing) was issued in 1937[1] and subsequently revised in 1951, but a vast number of non-standard sizes are widely in use. Many of these have only marginal differences in dimensions and lead to variety in other stationery goods (such as envelopes, which are available in more than forty sizes in the U.K.).

In contrast, the international standard series provides for sheets, each having sides in the ratio of $1 : \sqrt{2}$ (the basic sheet being 1 square metre in area), so that each size can be obtained by folding the preceding one in the series into two. This size relationship greatly simplifies stocking problems of different sizes and allows for paper cutting operations to be postponed until the demand pattern becomes clear.

The Case Studies

1. Studies of three consumers (one large college and two printers) revealed that while variety of ordered products was rather wide (e.g. twenty-five types of envelopes in eighteen sizes used by the college, several with only marginal differences), there were hardly any stocking problems as delivery was prompt and size specifications (whether standard or not) seem to present no difficulty to suppliers.

In the case of the printers, most of their work was carried out on standard sizes (only some of which were held in stock) and odd sizes were obtained either by cutting from the nearest B.S. size (the cost of wastage being negligible in relation to total cost of printing) or specially ordered (if required in large quantities). No major economies could be envisaged by variety reduction in these three cases, although the effect of variety on the printing schedules and on machine utilisation at the printers should be investigated.

2. Two case studies covered a large paper merchant and a medium size supplier specialising in printing paper. The sales distribution had a similar pattern in the two

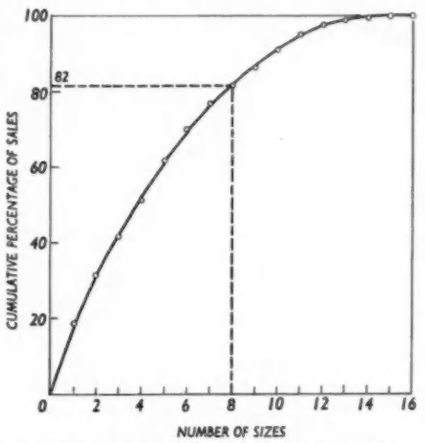


Fig. 1—Sales distribution for a paper merchant

cases in that 82 per cent. of the sales were secured by about half the number of sizes. Fig. 1 shows a six-months sales distribution for the paper merchant, who dealt in sixteen different sizes,[2] and while it appeared that some variety reduction was possible,[3] the main problem of variety seemed to be in quality rather than in paper sizes. Stocking problems did not appear to be significant (see Fig. 2), as in no case was over-stocking prevalent.

3. Two case studies were carried out at two paper mills with the view of finding the losses in output owing to resetting of machines, crop losses resulting from cutting wide reels into predetermined narrower reel widths and sheet sizes. As the mills aim at utilising machines at their maximum capacity, adjustments of deckels to alter the width of the machine paper web are rare and the width of the finished paper reel is therefore determined by machine specifications. Cutting into smaller widths is then a matter of appropriate combinations of customers' orders with the view of minimising the amount of left-over, which becomes waste.

One mill produced about 44,000 tons of writing and printing paper (about one-half

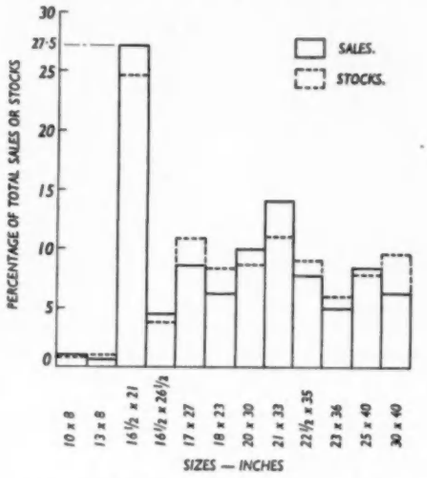


Fig. 2—Relation between sales and stocks of paper sizes in case study 4

in paper sheets and one-half in reels) per annum, 37 per cent to stock sizes and the rest to customer specifications. In a random sample of thirty orders it was found that the total crop losses amounted to 3·2 per cent, which, if taken as a representative figure, would be equivalent to about £70,000 per annum.[4] As it has been shown by scientific programming that waste can generally be reduced to below 1 per cent, it would appear that about £20,000 could perhaps be saved in this case on the reel orders alone.

In the other plant, a new paper mill providing a nominal trim width of 184in and an annual output of 12,000 tons was studied. On a random sample of thirty-two orders an overall crop loss of 2·5 per cent was found, equivalent to £15,000 a year (if this crop loss is taken as a representative figure).

Discussion of Results

The case studies indicated that the present pricing policy of paper (pricing by weight) does not discriminate against variety. The consumer can order any size he likes without being penalised, and this enhances variety in paper sizes. Furthermore, neither customers and printers nor wholesalers seemed to have significant inventory problems and the amounts held in stock were not found to be excessive.

The problem of variety came back to the

Table I—*Scheduling International Paper Sizes on Various Paper-Making Machines**

Item No.		Nom. width of M/c	Approx. trim width	No. installed	Cumulative No. installed	International Standard sizes which could be cut economically								Total width utilised	Wastage	Per cent waste
						AO 33·1	A1 23·4	A2 16·5	A3 11·7	A4 8·3	A5 5·8	A6 4·1	A7 2·9			
		In.	In.													
1	...	50	48	1	1	1	—	—	1	—	—	—	1	47·8	0·2	0·42
2	...	52	50	1	2	1	—	1	—	—	—	—	—	49·6	0·4	0·80
5	...	63	61	3	11	1	1	—	—	—	—	1	—	60·6	0·4	0·66
9	...	70	68	2	19	—	2	—	1	—	1	—	1	67·3	0·7	1·03
14	...	78	76	1	35	—	3	—	—	—	1	—	—	76·0	0	0·0
48	...	140	138	3	135	—	5	—	1	1	—	—	—	137·0	1·0	0·73
59	...	245	243	2	158	7	—	—	—	1	—	—	1	241·9	0·1	0·04

* A selection of seven machines out of fifty-nine types reported in use in 1960.

* Condensed from a detailed internal report by that title.

mills, and while the question of sizes did not generally affect the paper making process (all cutting being done subsequently), variety in quality meant resetting and re-adjusting machines with inevitable losses in production time.

Cost analysis of products was somewhat hampered by the fact that the firms concerned were reluctant to divulge full information. But it soon became apparent that while the break-even chart was difficult or sometimes impossible to apply, the amount of crop losses in paper cutting could be used as a sound measure of effectiveness.

Assuming that the figure of 2 to 3 per cent of crop losses is fairly general, this would be equivalent to about £1,000,000 per annum, or more, and it would appear that this loss could be reduced in three ways :

(1) *Reduction of Variety in Paper Sizes.*—Obviously, the smaller the variety the simpler the programming of the cutting operations and the better chance for specifying an initial machine width which will ensure smaller crop losses. Variety reduction would also greatly simplify storage and ordering problems and will decrease the pressure on the mills for quick delivery of odd sizes. The quantitative effect of variety reduction on inventory control, however, has not been adequately studied and further investigations are indicated.

The question of how variety reduction is to be achieved is very controversial, especially in a highly competitive industry such as this one. One way would be to introduce a modification—at least on a trial basis—in the pricing policy by penalising customers for specifying rare or non-standard sizes.

(2) *Scientific Programming of Cutting Operations.*—Combining orders to as near a full reel as possible can become a complicated task and substituting the present somewhat haphazard method by linear programming techniques may lead to substantial savings. This method has possible applications in other industries, such as in cutting steel sheets or strips, textiles or glass. One application in optimising the shearing of steel bars was discussed elsewhere by Eilon,[5] another study with special reference to paper cutting was published by Brien.[6]

A random order for five sizes, which would under the present method result in about 3 per cent crop loss, was taken in one of the case studies and expressed as a linear programming problem. This was solved by manual computations and yielded a crop loss of 0·53 per cent. It is noteworthy that in an example cited by Brien,[6] the loss could also be reduced to $\frac{1}{2}$ per cent and other examples suggest that crop losses below 1 per cent by scientific programming are quite realistic.

(3) *Introduction of International Paper Sizes.*—The international standard for paper sizes would greatly simplify the scheduling of cutting operations, because—as mentioned earlier—each size is a multiple of subsequent sizes in the series and combination of sizes does not directly contribute to crop losses.

The main problem lies in the variety of paper-making machines and their different widths. The 1960 *Philips Paper Directory* mentions fifty-nine different machines, their nominal widths varying from 50in to 245in. Clearly, combinations of international sizes may result in little or no crop losses on some machines and larger losses in others. It can be shown, however, that scheduling the international sizes will rarely cause this loss to exceed 1 per cent, the average wastage for all the machines listed being about one-third of 1 per cent. Selected examples for scheduling these machines are given in Table 1 (the trim width, on which this scheduling is based, was taken as 2in below the nominal width, to allow for trim cutting of the paper reels).

Conclusions

This inquiry—based on seven case studies—suggests that customers and wholesalers appear to be far more concerned with variety due to quality and colour, rather than variety arising from paper sizes. The present pricing policy, which is based on paper weight (and does not discriminate against non-standard sizes) and prompt deliveries by the mills result in comparatively small stocks being held by customers and wholesalers. The onus to supply the varied demand falls on the mills and the amount of waste resulting from cutting reels into predetermined sizes was selected as a useful criterion to determine the effect of variety on the plant. Random samples of orders suggested that crop losses amount to 2 to 3 per cent and it was shown that by reduction of variety coupled with scientific programming of the cutting operations, the loss could be reduced.

References

[1] Also formed the basis for B.S. 1413 : 1947 (dimensions of books) and B.S. 1808 : 1951 (commercial forms).
[2] Variations in quality and colour greatly increased this variety ; the medium size supplier has only twelve sizes, but in 170 different items.
[3] The four sizes carried by the one supplier, but not by the other, had a very low demand, and three of these four amounted to only 0·7 per cent of the total demand from the large supplier.
[4] The cost per ton waste was taken as £50, this being approximately the difference between the average value of paper and the value of pulp (the waste is repulpable).
[5] Eilon, S., "Optimising the Shearing of Steel Bars," *Journal of Mech. Eng. Science*, Vol. 2, No. 2, June 1960.
[6] Brien, G. O., "Minimising Waste in Strip Cutting," *ASME* SA-72, June, 1958.

Tolerances in the Prefabrication of Ships

By CARL-ERIK FREDRIKSSON*

We reprint an abstract of a paper having the above title which was read and discussed at the technical session held on the morning of Thursday, September 7, during the summer meeting of The Royal Institution of Naval Architects held in Gothenburg, Sweden. An account of the meeting appeared in our issue of last week, and included a summary of the paper.

INSTALLATION COSTS for a modern yard capable of building large ships are very heavy. The main factor raising these costs is the large size of the units involved. For ships of 10,000 to 100,000 tons deadweight units of at least 50 to 100 tons weight must be catered for. There is also the economic necessity for mass production covering an output of from 75,000 to 150,000 tons steel per year. The general acceptance of prefabrication methods in yards throughout the world appears to prove that the higher productivity at prefabricating yards can amortise and support a greater capital investment simultaneously with successful competition with the " plate-by-plate " yards. More and more conveying equipment is being installed in the shipbuilding industry. Combined with modern optically or tape-guided machines productivity is further increased.

With the advance of mechanisation the craftsman is disappearing. Somehow accuracy in production must be maintained, if not increased. A practical way is to introduce tolerances and control departments in the yards.

Tolerance requirements are concerned with :

Accuracy in machining ; accuracy in prefabrication ; and quality requirement.

Accuracy in Machining

Plates.—To obtain minimum welding costs in the automatic welding of heavy plane plates edge to edge a tolerance in straightness of $\pm 0 \cdot 3$mm is necessary. If the welding is done manually a tolerance of $\pm 1 \cdot 2$mm is adequate. The last-mentioned tolerance-range is four times as great as the former, but in joining heavy plates of thickness $>$20mm the labour cost for manual welding is about six times that for automatic-welding.

If the fitting is poor the cost of fillet welding will mount rapidly. The volume of deposited metal is defined by the accuracy achieved in the plater's shop. The author proposes the following tolerance requirements :

Length and width	$\pm$2mm
Straightness at plate edge for automatic welding...	$\pm 0 \cdot 30$mm
Straightness at plate edge for manual welding...	$\pm 1 \cdot 2$mm

Straight Sections.—For large tankers a high proportion of sections used must be delivered to the assembly shop in a straight condition. With modern working methods it is possible to maintain a length tolerance of $\pm$2mm for lengths of 10m to 12m.

Curved Sections.—The length tolerance is greater than for straight sections and is likely to be of the order of $\pm$5mm.

Tolerances Guaranteed by the Steel Mills.—At an early stage in the investigation of production accuracy it became clear that the tolerances guaranteed by the steel mills were not always satisfactory.

The following are typical samples :

Flat irons :	
Breadth $\leq$ 50mm	$\pm$1mm
Breadth $>$50mm...	$\pm$2 per cent
Length	$\pm \frac{1}{0}^{00}$mm (normally)
Angle bars :	
Flange width $\leq$75mm ...	$\pm$2mm
Flange width 75mm–100mm	$\pm 2 \cdot 5$mm
Flange width $>$100mm ...	$\pm 2 \cdot 5$ per cent (max $\pm$ 4mm)
Length	$\pm \frac{1}{0}^{00}$mm (normally)

The steel mills do not normally guarantee straightness ; when given, 2·5 per mille is the usual figure. Flat irons as well as sections can be bought with length tolerance $\frac{+6}{-0}$mm, but are subject to an extra charge (at present about 8 per cent).

In large tankers flat irons are used extensively and may have depths up to 500mm to 600mm. With a guarantee of $\pm$2 per cent on depth the shipbuilder may have to make a smooth butt joint in bars of depth differing by as much as 20mm. This tolerance guarantee is inadequate from structural strength as well as cost point of view. When sections of various depth are to be led through bulkheads the watertightness as well as production cost becomes a matter of concern.

* Eriksbergs Mek. Verkstads AB., Gothenburg, Sweden.

If the following tolerances could be guaranteed, the structural strength would be improved and the scope of prefabrication extended.

Breadth and depth ...	±2mm
Length	±5mm
Straightness	±1 per mille (at L⩾8m)

Accuracy in Prefabrication

Tolerances in finished units are affected by the following factors: Tolerances in the machined elements; shrinkage effect of welding; assembly faults during prefabrication.

The size and shape of the unit are also important factors. It is much easier to obtain a narrow tolerance-range on a plane, stiffened bulkhead than on a bow unit. Two-dimensional units can be produced with a tolerance of ±2mm. However, it is not unusual that one of the main dimensions is easier to keep inside a narrower tolerance-range than the other. Sometimes it is necessary to burn to size in the prefabrication shop on completion of welding.

On three-dimensional units it is only with great difficulty that the main dimensions can be kept within a tolerance-range of ±5mm. It is therefore common practice to burn to size on completion of all welding of

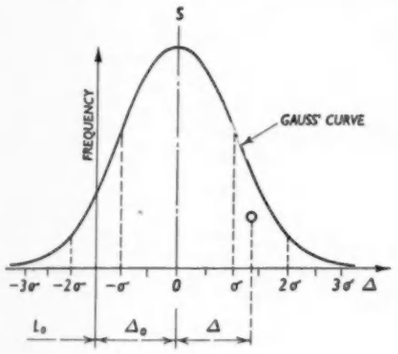


Fig. 1

the unit. This burning may be done in the prefabrication shop, but generally it is done on the berth. Neither the quality nor cost of burning on the berth can compare with shop burning. Poor burning leads to an increase in deposited weld-metal and to increased building costs.

Units completed to "finished dimensions" can be delivered from the prefabrication shop to a limited extent only. The fitting of units on the berth is often very expensive. There is a need for improved measuring tools and the Russian shipbuilding journal *Sudostroenie*, No. 1/61, contains a brief description of an optical measuring instrument which seems to be a step in the right direction.

Quality Requirements

The quality of welding is dependent on the individual welder's skill and sense of responsibility. The introduction of automatic equipment and improved welding rods has reduced the importance of the human element.

Improved accuracy in machining and prefabrication as specified above is very important for the achievement of first-class welding and efficient hulls. This is accompanied by reduction in volume of deposited weld-metal, which in turn results in lower production costs.

There is talk about the use of steel of higher ultimate tensile strength. Such steels will reduce steel weight but will increase the need for still better welding quality and accuracy of fitting.

Proposals in Terms of I.S.A.-Tolerances (I.T.)

The proposed tolerances (±2mm) would be classified in accordance with I.S.A.-system as follows:

Table I

Nominal length, m	Basic tolerance
1–3	IT 15
3–7	IT 14
7–14	IT 13
>14	IT 12

Are the Proposed Tolerances Realistic?

It is felt there may be some justification for questioning the realism of the proposed standards. Despite the fact that they lie in the coarsest range of I.S.A. classification the proposed tolerances can be very hard to attain with present working methods. On the basis of an investigation into pre-fabrication methods on a large scale over the last five years the following tolerance limits were found to be practicable.

The tolerance-ranges were calculated according to conventional statistical methods based on large control measurement data. The figures presented in Table II can only be considered as representative of the size of the tolerance-range.

Based on the experience gained in that section of the production where intensified control has been established the author claims that the proposed tolerances are realistic although the results achieved in the yard as a whole are somewhat less exact.

Table II

	Tolerance, mm
Machining	
(a) Plate-work (nominal length>10m)	
(1) Optically-guided burning machine on scale 1 : 10	±2·8
Including: Production of templates; The shrinkage of template material; Burning machine	
(2) Manual work...	±4
Including: Production of templates; Marking off; Manual burning	
Excluding: Template material	
(b) *Sections*	
Manual work...	±5
Prefabrication (Nominal dimension ⩾10m)	
(1) Two-dimensional units without correction after welding	±3·4
(2) Two-dimensional units including correction after welding	±2·2
(3) Three-dimensional units	±6·5

Some Basic Principles on Control Work

It is difficult to establish a precise figure for the production accuracy of a machine. Errors vary both as to size and frequency. However a methodical series of measurements followed by a mathematical analysis can solve the problem.

Very briefly the technique is as follows.

If the measurements are plotted on a frequency-deviation co-ordinate system and are sufficiently numerous the result represents a figure enveloped by the Gauss curve.

$$Y=\frac{N}{\sigma\sqrt{2\pi}}e^{\frac{-Z^2}{2\sigma^2}}$$

where

Y=Frequency
σ=Standard-deviation
Z=Variable (calculated from results of measurements)
N=Total number of measurements

This curve has an axis of symmetry (s). The difference Δ_0 between a nominal figure (L_0) and the symmetry axis is called "the system error." The area below the curve represents the number of measurements made.

$$\text{Area}=\int_{-3\sigma}^{+3\sigma} y\,d\,\Delta$$

According to Fig. 1 every measurement result can be expressed by the equation:

$$L=L_0+\Delta_0+\Delta$$

where L_0 and Δ_0 are constants and Δ varies according to the individual result.

For practical purposes the significant terms Δ_0 and σ can be considered as follows:

Δ_0=system error, also called mean deviation=a deviation common for every measurement. This deviation can at a final stage of production be said to have been built up of errors from previous stages. To find out which factors are involved and the effect of every single factor would be a very difficult task. On the basis of actual measurements however, we have found how great their added effect is and we can choose a suitable stage, at which to make a general correction.

σ=standard deviation gives information as to how much production varies. A general correction as the case of system error cannot be made. In the case of a machine steps can be taken for improvements and afterwards the effect on accuracy (Δ_0 and σ) can be calculated. For an entirely manually-operated station it is more difficult to make improvements.

From investigation it has been found practicable to set a tolerance of $T=1{\cdot}44\ \sigma$, which covers 85 per cent of production.

The really important thing is, that the management has the means of ascertaining the effect on accuracy of measures taken.

According to the author's experience errors normally affect σ only and not Δ_0.

Optimum Tolerances

Since the tolerance question has now been investigated from a general point of view, let us return to the optimum tolerance, and define it as the tolerance at which production is most profitable.

Too narrow tolerances are uneconomic. and productivity suffers and with rising costs

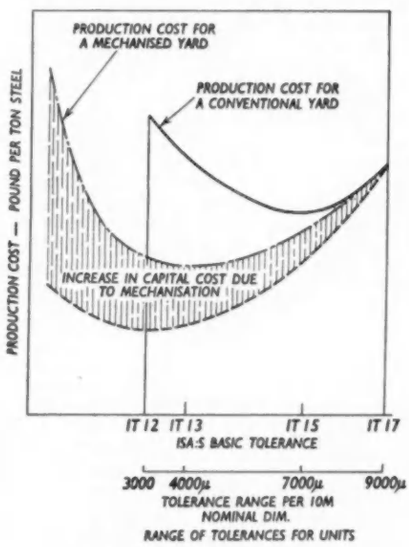

PRODUCTION COST FOR A MECHANISED YARD
PRODUCTION COST FOR A CONVENTIONAL YARD
INCREASE IN CAPITAL COST DUE TO MECHANISATION
PRODUCTION COST — POUND PER TON STEEL
IT 12 IT 13 IT 15 IT 17
ISA:S BASIC TOLERANCE
3000 4000μ 7000μ 9000μ
TOLERANCE RANGE PER 10M NOMINAL DIM.
RANGE OF TOLERANCES FOR UNITS

Fig. 2—Optimum Tolerances

of control production costs also start increasing when the optimum point is passed. The author's conclusions are summarised in Fig. 2. According to the curves the optimum points are at 7000μ and 4000μ for conventional

and mechanised yards respectively, but can vary with wage levels. The foundation for accurate production is to be laid in template production and in machining; this entails increased capital costs, but modern precision machines have proved very productive, which offsets the increased capital costs. Profits are mainly made in the prefabrication shop and on the berths, where the focal points of production costs are to be found. Alongside these primary benefits, there are secondary advantages. Thus accuracy in production creates favourable conditions for effective planning. Effective planning may make the last 15–20 per cent of production possible. Considering that in many cases the first 60–70 per cent of normal production is essential to cover the firm's fixed costs, the remaining production has a most important bearing on the rate of profit.

OBITUARY

SIR ELLIS HUNTER

We regret to record the death of Sir Ellis Hunter, which occurred on September 21, at the age of sixty-nine. Ellis Hunter was born on February 18, 1892, at Great Ayton, Yorkshire and educated privately. He then served articles with a local firm of accountants, qualifying as A.C.A. in 1914 and becoming F.C.A. in 1927. In the 1914–18 war he first came into contact with the iron and steel industry, being employed by the Ministry of Munitions in connection with iron and steel works expansion and the limitation of profits. He became a partner in the firm of W. B. Peat and Co., and later, when the business amalgamated with others to become Peat, Marwick, Mitchell and Co., he was admitted as a general partner of the new concern.

In the early nineteen-thirties he renewed his contact with the steel industry, and in 1938 joined the board of Dorman Long and Co., Ltd., as deputy chairman. Shortly afterwards he became managing director of Dorman Long, retaining his executive position with this company until his retirement in March this year. Ellis Hunter was not only prominent in the affairs of his own company, guiding it through the difficult war years and the rehabilitation period afterwards but also took a great interest in the activities of the British Iron and Steel Federation, becoming President in 1945, at a time when the industry was the centre of great political controversy. As President of the Federation he took a leading part in drawing up the first post-war steel development plan, and the value of his services to the Federation was reflected in the fact that he remained President until 1953, a much longer period than the customary two years.

During his service with the Federation Sir Ellis (he was knighted in 1948) retained his interest in Dorman Long, and carried through his company's £100 million development plan, financing the work out of retained profits to a much larger degree than was the general practice at the time. This resulted in the payment of modest dividends to shareholders for a number of years, and provoked criticism in some quarters, but Sir Ellis refused to be deflected from the course he had chosen and believed to be right. In his administrative work at Dorman Long he was noted for his encouragement of younger men, and in 1944 he introduced a class of executive known as special director. These were officials of the company who were, by virtue of their special appointment, able to assist the board in policy decisions, and the scheme provided a valuable recruiting ground for future board members. Several of the first special directors have since become full board members, their places having been taken by younger special directors.

From 1938, when he joined Dorman Long, Sir Ellis confined his activities almost entirely to that company and its subsidiaries and to the Federation, his only outside connection being his membership of the Court of Directors of the Royal Exchange Assurance Company, Ltd. He became a Knight Grand Cross of the Order of the British Empire in 1961.

DR. T. P. COLCLOUGH

We regret to have to report the death last Friday of Dr. T. P. Colclough, one of the most respected men within the iron and steel industry of this country and one with a world-wide reputation. Many even amongst those who knew him quite well will be surprised to learn that he was as much as seventy-six years old. He was technical adviser to the British Iron and Steel Federation at the time of his death, a post he had held since 1945.

Dr. Colclough was not amongst those who make names for themselves by becoming heads of great companies; nor was he a great discoverer or inventor, great though his interest in research remained right up to the day of his death. Nor, though he joined the Brown-Firth laboratories in Sheffield at the time when Dr. Hatfield was in charge in 1916, was appointed chief chemist of the Park Gate Iron and Steel Company, Ltd., in 1920, advancing rapidly to higher posts in the next nine years, and became technical director of H. A. Brassert and Co., in 1929, do we think his name will ever be closely associated in anyone's mind with any individual company. For Dr. Colclough was ever the adviser. His grasp of technicalities was immense. So too was his ability to weigh advantages against disadvantages; and he could express his thoughts with great clarity. There is, of course, more to advising than offering good technical advice. It is necessary also to "get on" with those to whom the advice is offered. Dr. Colclough did "get on" with people.

It was with H. A. Brassert that he really began to make his mark in a way likely to make him widely known. For there as technical director he became connected with the planning and design of large steel works and also had advice to offer about the kinds of plant most needed by, and which he felt ought to be erected by, the industry in this and, indeed, in other countries too. Very soon after the success of his work at places such as Corby and Ebbw Vale had been established Dr. Colclough's advice was being sought upon the Continent of Europe and as far afield as China and New Zealand. He began to travel widely.

From 1942 to 1945 Dr. Colclough, like so many other able men, was drawn within the orbit of a Ministry. He acted as technical adviser to the Iron and Steel Control of the Ministry of Supply; and for this work he was appointed C.B.E. in 1950. From 1945 onwards he was technical adviser to the British Iron and Steel Federation and was able to travel even more extensively than before and to do work in several countries. He was at various times technical adviser to the Control Commission in Germany, technical adviser to Iscon, the consortium responsible for building the Durgapur steel works in India, and a member of the Royal Commission on the steel industry of Southern Rhodesia. He also led iron and steel missions on behalf of the Federation to Russia, Poland and Jugoslavia. He became a council member of the British Iron and Steel Research Association in 1950, his interest in the work of that body having extended further back.

Dr. Colclough was the recipient of the highest award that it is in the power of the Iron and Steel Institute to bestow, the Bessemer Gold Medal, and less than a year ago he was elected an hononorary vice-president of that Institute.

Technical Reports

The Resistance of Certain Timbers in Sea Defence Groynes to Shingle Abrasion. By A. C. Oliver and R. P. Woods. The Timber Development Association, Ltd., 21, College Hill, London, E.C.4. Price 3s. 6d.—The advantages of timber as a material for sea defence groyne constructions are reviewed. Shingle abrasion of timber in sea defence groynes—the two main types of wear are caused by "spill over" and "scour"—are discussed. Rates of wear of piles and planking have been measured on groynes made of seven different timber species installed on the Lancing (Sussex) coast. The zone of greatest wear is defined. The results are presented graphically. Marine borer attack on the sea end of groynes is discussed.

Pinch Collapse (A.E.R.E.-R3383). By K. Hain, U.K. Atomic Energy Authority. H.M. Stationery Office. Price 5s.—This report is the first of a series of papers dealing with numerical methods for solving the pinch collapse in plasmas. The series will describe a joint effort between the Atomic Energy Research Establishment, Harwell, and Max-Planck-Institut für Physik and Astrophysik, München, to set up general programmes for big computers to calculate the pinch effect. A fully ionised plasma is assumed. To this plasma cylindrically symmetrical magnetic fields are applied, thus causing a pinch collapse. The plasma is treated in hydromagnetic approximation, including electric and thermal conductivity.

Rüttelbeton. By K. Walz. Berlin: Verlag Wilhelm Ernst & Sohn, Berlin-Wilmersdorf, Hohenzollerndamm 169. Price DM.16.80.—The present third edition of this work, of which the first and second editions appeared respectively in 1943 and 1948, has undergone complete revision, in order to confine the treatment to a reasonable length. This could only be done by foregoing a complete description of existing equipment, and to concentrate instead upon what is typical. After describing the phenomena common to all methods of vibrating concrete, the author discusses the composition and structure of suitable mixes. Further sections deal with generalities in the operation of vibrators, and the design of shuttering and reinforcement, after which the principal types of vibrators are dealt with. The effects of overprolonged vibration and other matters, working techniques and quality control, and finally a brief survey of special applications conclude the book.

The Extrusion of Metals—Part VIII. Steel Under Cold Impact Conditions. By J. McKenzie and A. R. Rodger. D.S.I.R. National Engineering Laboratory, East Kilbride, Glasgow. No price stated.—Cold extrusion of various steels under impact conditions was investigated and the influence of various extrusion factors on the extrusion-pressure/punch-stroke characteristic, work done, process efficiency, metal flow and product properties was determined. The study of the effect of factors such as type of product, die geometry, punch impact speed, lubrication, slug condition and shape was confined to the extrusion of a 0·15 per cent carbon mild steel. In the study of the effect of reduction, a range of steels with carbon contents up to 1 per cent and alloy steels such as En 33 (3 per cent nickel), En 40B (3 per cent chromium) and En 58B (18/8 austenitic) was extruded. From considerations of tool stress the extrusion ratios were limited so that a maximum extrusion pressure of 180 tons per square inch was not exceeded. A few tubes were extruded at pressures over 200 tons per square inch without tool failure. A linear relationship between maximum extrusion pressure and the logarithm of the extrusion ratio satisfied the experimental results above an extrusion ratio of 1·8. The pressures on the die face, in the extrusion of rod and tube, and on the punch face, in the extrusion of can, are shown to have a minimum value at, or near, an extrusion ratio of 2. The extrusion characteristic, maximum pressure, metal flow, product hardness and dimensional accuracy were found to be dependent on the entry profile of the die.

Self-Contained Sea-Water Distillation Plant

A SELF-CONTAINED sea water distillation plant of 25,000 gallons per day capacity has recently been shipped from the works of Bennis Thermoflash, Ltd., to the Government of Abu Dhabi on the Arabian Gulf. It consists essentially of a distillation unit, a steam generator and a diesel-driven alternator for driving the pumps and other auxiliaries.

Water is drawn from the sea into the plant by the feed pump, through a coarse strainer at the end of the suction pipe and a fine duplex strainer adjacent to the plant. It is then circulated through the vapour condenser and feed heater tubes of the eleven-stage distillation unit, its final temperature being 186 deg. Fah. It then flows in series through a number of flash chambers maintained at progressively higher vacua, the final stage operating at a vacuum of 28in Hg. The water boils vigorously, or flashes, in each chamber, and vapour is produced. The vapour passes through separators in the form of a blanket of knitted monel wire mesh, which effectively removes entrained moisture particles. The vapour then condenses on the outside of the condenser tubes, its latent heat passing into the incoming feed water, the temperature of which is progressively raised. The sea water remaining behind in the final flash chamber is discharged from the plant by the brine pump. The condensate is collected in each condenser and cascaded down to the final stage, whence the distillate pump delivers it either to the storage tank built into the plant, or directly for consumption.

An Electro-Katadyn unit is incorporated into the plant which sterilises the distillate by putting a stream of silver ions into the distilled water passing through it.

As the feed water boils upon entering the first flash chamber, the dissolved gases liberated pass into the condenser with the vapour, where they tend to remain behind after condensation. To prevent blanketing of the tube nest, the gases are removed by steam ejector and discharged to the atmosphere. Another ejector at the final flash chamber removes the small quantity of gases released after the first stage, and also compensates for any air leakage into the unit from the atmosphere. The latent heat of the steam from both ejectors is conserved by passing the ejector discharge into the feed heater.

Steam is provided by a Clayton steam generator. A storage tank for boiler feed water is built into the feed heater of the distillation unit. Water from the storage tank is pumped by the boiler feed pump to an accumulator, the pump being started and stopped by a liquid level control in the accumulator. A circulating pump draws water from the accumulator and delivers it to the single-pass spirally-wound heating coil, so that it is in counterflow to the combustion gases that are passing over the outside of the coil. Upon leaving the generating section, the fluid passes through the thermostat tube and is delivered through a helically wound water wall tube to the separator in the accumulator, where dry steam is separated and delivered through the steam outlet to the distillation unit. The unevaporated liquid falls to the lower section of the accumulator for recirculation. The steam generator is fitted with an automatic blow down device which maintains the dissolved solids in the circulating water at an acceptable concentration, the quantity of blow down being adjustable, and being automatically proportioned to the feed water rate.

Very little feed water treatment is required. The chemical injection pump is built into the boiler maintains the pH value of the boiler feed water at about 10. The distillate used for make-up contains approximately 50 p.p.m. of NaCl, and has a pH value of 6·6 to 6·8.

The steam space of the feed heater operates at atmospheric pressure, any dissolved gases from the boiler feed water or from the ejector discharge being blown directly into the atmosphere, so a novel method of cooling is employed on the diesel engine. Water from the boiler feed storage tanks is pumped to the diesel engine jacket at 212 deg. Fah. Cooling is effected in the jackets by partial vaporisation of the water, i.e. vapour phase cooling, and the resulting mixture of water and vapour is returned to the feed heater, where the heat generally wasted in a jacket cooler is conserved by being transferred into the feed. On full output of the distillation unit, the diesel generator produces approximately 50 lb per hour of steam, which represents about 2 per cent of the total consumption. The total consumption of fuel oil is stated to be less than 1 gallon per 50 gallons of water produced.

The diesel alternator sets comprises a standard three-cylinder Dorman engine driving a standard alternator, the engine being rated at 35 b.h.p. and the alternator at 25kW. The output from the alternator is fed direct to the automatic control panel for distribution to the various pumps and control devices. The control panel carries all the instrumentation for the distillation unit and diesel generator, and incorporates pressure and vacuum gauges for sea water and vapour, together with a distillate flowmeter and a distillate salinity indicator. It also incorporates certain safety devices which shut down the whole plant in the event of alarms, such as flooding of the unit, failure of the feed pump or its motor, or of the brine pump or its motor.

The illustration shows the distillation unit in the centre, with the steam generator on the right and the diesel alternator set on the left. Below the distillation unit is the Electro-Katadyn steriliser, to the left of which can be seen the four take-off connections for the distilled water produced. The control panel is mounted on top of a distilled water storage tank, and beneath the steam generator is the fuel oil storage tank.

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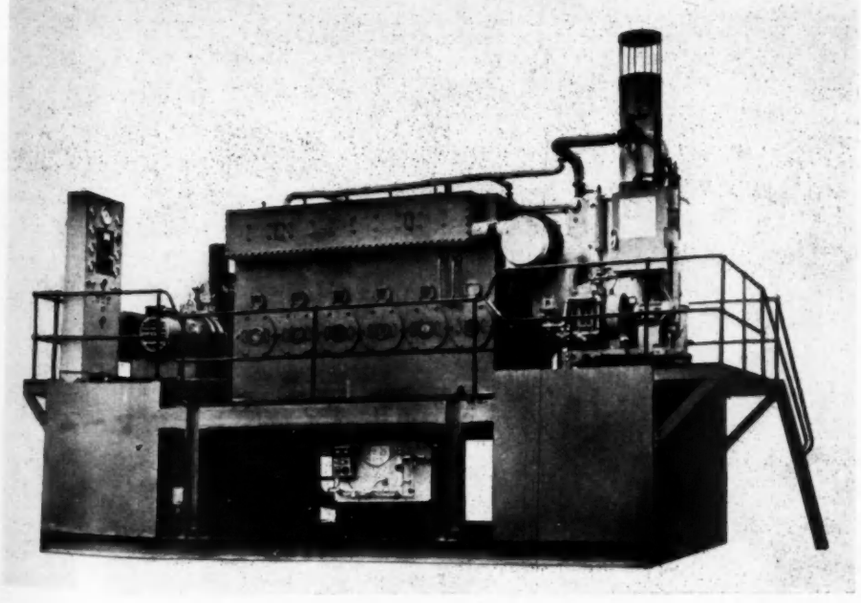


Distillation plant of 25,000 gallons per hour capacity

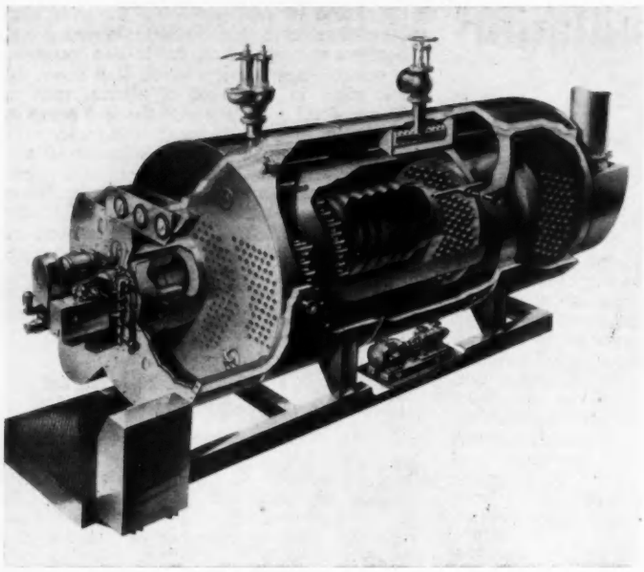
Service Plan for Shell Boiler Installations

A NEW service, named "The New Plan," has been inaugurated by John Thompson (Wolverhampton), Ltd., and offers the small, medium and large industrial steam user the benefits conferred by a "packaged deal" when installing new or extending or modernising steam-raising plant. "The New Plan" affords the purchaser relief from the administrative and supervisory detail associated with the choice of self-contained works-tested package boilers and avoids the limitations of too rigidly standarised units. It ensures, by reason of a wide choice of units and auxiliaries and overall flexibility of design, that in gaining convenience and simplicity nothing is conceded of efficiency or operating economy. To provide this range of choice and flexibility two new ranges of boiler units have been added to the company's proved ranges. To achieve optimum results it is essential to have the support of reliable ancillary services, and in this respect the company has group associates specialising in controls and instrumentation; mechanical stokers, coal and ash handling; pipework; water treatment; steelwork and chimneys, &c., all of which are available. Thus under "The New Plan" the company can provide "packaged" plant in three forms: as complete oil- or coal-fired self-contained automatic boiler units, works tested and delivered to site ready for operation immediately the services have been connected; as a packaged installation in which one or more units are installed together with all auxiliary equipment, the whole design and construction being the company's responsibility; or as a completely designed packaged boiler-house. An example of the latter is the new steam generating station at the Treforest Industrial Estate, in which eight John Thompson Super Economic boilers each of 28,000 lb per hour capacity will meet a load of 180,000 lb per hour.

NEW SHELL BOILERS

The new ranges of shell boilers include oil-fired and coal-fired units which can be supplied as conventional boilers when required. The oil-fired boiler, of which we include a cutaway view, is of three gas pass design, incorporating a wet-sided, dry-backed combustion chamber with an offset flame tube. The latter, together with the inclusion of internal steam/water baffles, gives a positive circulation and steam separation generally associated with water-tube boilers. The internal baffling ensures that the cold incoming feed-water first flows over the third gas pass and so reduces the gas outlet temperature and increases efficiency.

Increased radiant heating surface is achieved by the corrugated flame tube in a minimum length and with the maximum flexibility, together with the wet-sided, dry-backed combustion chamber; a refractory back to the combustion chamber is provided, assisting combustion in the radiant heated area before the gases enter the smoke-tubes and resulting in smokeless chimney gases and absence of fouling. The boiler can be offered as a standard unit, incorporating a Hamworthy fully automatic rotary cup, forced draught burner burning fuel oil of up to 6000 seconds viscosity (Redwood No. 1) at 100 deg. Fah. and giving a modulation over a 3 : 1 turndown ratio. However, any make of burner conforming to suitable design characteristics can be supplied with the boiler. To



Oil fired boiler with wet sided, dry backed combustion chamber and offset flame tube

enhance quiet operation and further the compact design, the f.d. fan is mounted under the boiler.

The boiler unit is supplied on a baseplate, complete with all fittings and mountings to comply with the A.O.T.C. requirements for unattended boilers. It is available in a number of standard sizes, covering a range from 5000 lb to 19,000 lb per hour F. and A., 212 deg. Fah. at a working pressure of either 110 lb or 145 lb per square inch gauge, though increased pressures can be met to suit specific requirements.

The automatic coal-fired boiler, with coal and ash handling facilities which necessitate periodic attendance only, offers operating advantages previously associated only with oil-fired boilers. As with the oil-fired unit this boiler has a wet-sided, dry-backed combustion chamber, with three gas passes, which offers improved thermal efficiency, and, together with the fully corrugated flue, gives maximum radiant heating surface.

Though the boiler can be supplied to comply with any coal-handling arrangements, the standard model had been designed for firing by a " Mini-Stoker " chain grate stoker manufactured by John Thompson (Triumph Stoker), Ltd. This stoker has a works-set low firing rate and an easily adjustable high-firing rate which can be simply preselected by the operator to meet any anticipated load. Change over during operation between low and high-firing rate is effected automatically by boiler pressure. All necessary automatic control gear is supplied and fuel bed thickness is governed by the adjustable guillotine. Ash is deposited directly into an ashbox under the boiler via a water-cooled opening through the bottom of the combustion chamber and boiler shell. Close machining tolerances and the " balanced draught " design virtually eliminate air leakage into the boiler.

A minimum of operating surveillance is necessary, the ashbox and stoker coal hopper on the smaller boilers being designed to give four hours' unattended steaming at M.C.R. The coal-fired installation, when supplied as a completely integral unit, includes a screw type elevator for filling the stoker hopper. The boiler is produced in a number of sizes ; up to 13,000 lb per hour F. and A., 212 deg. Fah., at a working pressure of 110 lb or 145 lb per square inch gauge. The boiler, feed pump, f.d. and i.d. fans, with full complement of valves, controls and mountings, are mounted on a base frame for installation on a flat concrete floor.

Both boiler units are of all-welded construction, the shells being fusion welded and manufactured as class I vessels. The flue tube is welded in at each end, and all smoke tubes are expanded into the end plate and seal-welded. Tests and trials have indicated that efficiencies exceeding 80 per cent are easily attained under varying load conditions.

The advent of a self-contained and (to a degree) automatic coal-fired " package " unit makes possible the reconsideration of the use of coal and exploitation of substantial economical advantages which previously many steam users have had to forego in order to achieve the clean operation, unattended working, or convenience offered by other forms of fuel or other means of heating. In addition, the coal-fired unit design places emphasis on clean operation.

Hydrostatic Transmission Equipment

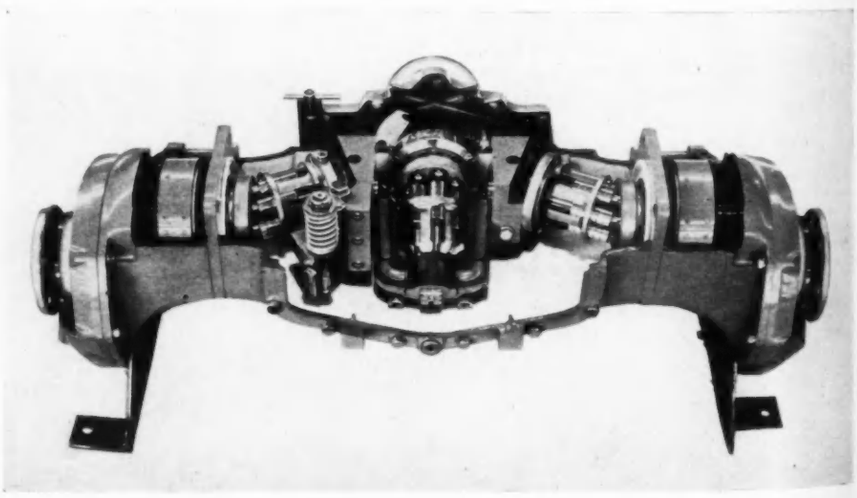
A LICENCE has been acquired by the Plessey Company, Ltd., for the manufacture in this country of the hydraulic equipment developed by the Guldner-Moteren Werke in Germany which has been in use for some years to provide hydrostatic transmission systems on a number of types of vehicles as well as in industrial applications. The hydrostatic transmission equipment to be made by Plessey will cover nominal ratings between 2 and 125 h.p. and within it there will be ten fixed displacement and ten variable displacement pumps and motors, evenly stepped in capacity. By use of the standard units a wide range of torque conversion requirements can be met, and, in addition special unit transmissions have been developed for use in vehicles and boats.

A typical transmission system for a vehicle which is to be seen in the accompanying illustration shows the general construction and principle of the equipment. In the axial piston pumps and motors used the driving plate is integral with and normal to the driving shaft, and the cylinder barrel and piston assemblies rotate in unison with the plate. The capacity of the unit is determined by the angular displacement of the cylinder barrel, the housing of which is supported on trunnion bearings. The cylinder barrel is mechanically coupled to the driving (or driven) shaft only by the connecting rods and pistons which form the constant speed universal coupling between the two. This cylinder barrel is carried on a central spindle secured to the valve plate and it is stepped in such a way that a pressure balance is achieved and ensures a correct bearing pressure on the valve plate.

Variable capacity units can be controlled either manually or by a detachable servo actuator. In a transmission system comprising a variable displacement pump and fixed displacement motor, the pump can be fitted with a control unit to give a constant maximum horsepower output. This control is a pressure sensitive servo positioner and it is designed to ensure the most efficient use of the prime mover without overloading the hydraulic equipment. The variable volume pumps are designed for immersion in the hydraulic fluid reservoir. Integral with a variable volume pump assembly are two detachable gear pumps, one supplying fluid to operate the servo control and the other to provide a boost to the inlet and maintain the required circulation of fluid for cooling and lubrication under working conditions. This construction gives a compact installation with a minimum of external pipework.

To meet the special requirements of a small vehicle capable of carrying 2 tons at speeds up to 20 m.p.h., the complete transmission system shown in the illustration has been incorporated in an axle unit. This equipment comprises a variable volume pump, under direct pedal control, and two motors. Each wheel is separately driven by its own motor through a spur reduction gear. The axle casing constitutes the hydraulic fluid reservoir of four gallons. An external cooler required in this case takes the form of an annular tube surrounding the propeller shaft. This axle assembly replaces a conventional clutch, gearbox, final reduction gear and differential. Since the torque conversion is positive and smoothly progressive through zero speed to reverse, only parking brakes need be incorporated in the unit.

A " Hydrocar " industrial truck incorporating this design of axle was recently demonstrated at the Swindon works of the Plessey Company, Ltd., where new production lines are being laid down for manufacturing the hydraulic equipment. The truck engine was controlled by a hand-set variable datum governor to ensure that it ran consistently at its best economic speed, and actual driving called only for steering and operation of two pedals controlling speed and direction of travel. We found that an experienced driver could in less than a minute fully master the controls, and a complete novice could acquire the basic driving principles in a few minutes. To date this class of transmission has been applied to a wide variety of mobile and other industrial equipment.



Axle unit incorporating a complete hydrostatic transmission system. The trunnion-mounted variable displacement pump is positioned in the centre of the axle with the fixed displacement pumps on each side driving the road wheels through reduction gearing

SHORTER REPORTS

Active Communications Satellite

FOLLOWING an agreement between the U.S. National Aeronautics and Space Administration and the American Telephone and Telegraph Company, the Post Office is to participate in tests of a new communications satellite known as Project " TSX ". This is an active satellite being designed by the Bell Telephone Laboratory, and is to be launched by N.A.S.A. early in 1962. The tests are to include the transmission of television signals and multi-channel telephony between the A.T.T. Company's ground station at Rumford, Maine, U.S.A., and the ground station which the Post Office is erecting on the Lizard, Cornwall. These tests are additional to those announced earlier this year (THE ENGINEER, July 14, 1961, page 65), which involve Project " Relay," an active satellite, and Project " Rebound," a passive balloon reflector satellite. Project " TSX " is expected to provide additional design information concerning satellite communication systems ; in particular, it is to use higher frequency bands than those planned for Project " Relay."

British Computer Society

ANOTHER rise in membership, to over 2200, is shown in the fourth annual report of the British Computer Society, presented to members at their annual general meeting on September 26. During the year the licence of the Board of Trade was granted to dispense with the word " Limited" in the Society's name ; new work began on data transmission and character recognition ; a move was made to co-ordinate activities in evolving standards for the computer field ; and increased activity took place internationally. The Society's third conference will be held in Cardiff in September, 1962.

Annual prizes for published papers were awarded at the meeting to Dr. H. H. Rosenbrock (Constructors John Brown, Ltd., Leatherhead, Surrey) for his paper " An Automatic Method for Finding the Greatest or Least Value of a Function "; and to Mr. A. J. Platt (Pilkington Brothers, Ltd., St. Helens, Lancs.) for his paper on " The Experience of Applying a Commercial Computer in a British Organisation." Mr. D. W. Hooper, M.A., F.C.A., Chief Organising Accountant of the National Coal Board, took office as the Society's president in succession to Dr. F. Yates, F.R.S., who becomes a vice-president. Mr. H. W. Gearing, B.Sc.(Econ.), F.C.I.S., F.I.S., (The Metal Box Company, Ltd.) and Mr. A. Geary, M.Sc., (Northampton College of Advanced Technology) were appointed as new vice-presidents.

Polarised Proton Source

A DEVICE which produces polarised protons has been installed on the 50 MeV proton linear accelerator (P.L.A.) at the Rutherford High Energy Laboratory of the National Institute for Research in Nuclear Science, Harwell, and has been in successful operation since February this year. It provides a beam of protons which are 32 per cent polarised at an average intensity of 3×10^7 protons per second. A polarised beam is one in which the protons are spinning predominantly in a fixed direction relative to their direction of motion. Nuclear forces are known to be spin dependent, and because of this, if the beam of particles is polarised it enables a greater range of experiments to be performed, and consequently more detailed information can be obtained about the particle interactions. The successful development of this source is therefore of considerable importance. Although several other laboratories are known to be working on similar projects, it is believed that this is the first source to be installed on a large accelerator and to produce a beam of protons of sufficient intensity to be useful for nuclear experiments.

The source works as follows. Hydrogen atoms are produced from molecular gas by a radio-frequency discharge. These atoms then pass through a highly non-uniform (six-pole) magnetic field in which atoms with positive magnetic moment are deflected away from the axis and removed while the atoms of negative magnetic moment oscillate about the axis and emerge from the magnet as a well-defined beam. By bombarding this beam with a current of electrons the atoms are ionised, and the resulting protons which are then extracted and injected into the linear accelerator are polarised. This polarisation is preserved during acceleration.

The polarised proton source is located on the 500kV terminal of the d.c. injector of the accelerator. Thus it was necessary to make the vacuum equipment, comprising seven pumps, the control equipment, refrigerators and water-cooling plant, completely self-contained and self-monitoring. The experimental work in the laboratory followed by the engineering design and manufacture took about three years.

[Reply Card No. 1213]

Aerials for Guided Missile Training

FIVE aerials and associated synchronisation equipment are being supplied by Cossor Radar and Electronics, Ltd., Harlow, Essex, for use by the War Office at Trials Establishment, Guided Weapons, Royal Artillery, on the coast of Anglesey. The equipment consists of five helical aerials, together with means for slaving these to the bearing and elevation read-out from a master-tracking apparatus.

Two of the five aerials are for use with dual-purpose transmitters in the 100 Mc/s region. Of these, one is kept in a " standby " condition. Signals transmitted from the other aerial interrogate equipment carried by the airborne missiles, and the reply signal is received in the 200 Mc/s region by a third aerial. The remaining two aerials operate in the 400 Mc/s region, and receive other telemetered information from missiles in flight.

The unusual form of helical aerial is seen in the accompanying illustration. Aerials are circularly polarised, which is an important factor in this application, for some missiles spin whilst in flight, and circular polarisation minimises unwanted signal modulation. Use of the helical aerial also results in a structure more mechanically rigid than would be possible with alternative forms of aerial at these frequencies.

[Reply Card No. 1204]

Temporary Marine Engine Repairs

RECENTLY the m.v. " Baltistan," a cargo ship of 9620 tons deadweight built in 1953 by John Readhead and Sons, Ltd., and engined by the North Eastern Marine Engineering Company, Ltd., for the Strick Line, suffered main engine trouble while en route to the Persian Gulf. As a result of the trouble the engine crankshaft was badly distorted, but, instead of being towed a considerable distance to the nearest repair facilities, the engine builders evolved a special method of repair. This involved the fitting of eccentric bushes, to accommodate the distortion of the crankshaft, which were manufactured in the works to measurements taken at the ship. The replacement parts and technicians were flown out to carry out the repair and after satisfactory trials the ship sailed home under her own power and so demonstrated the practicability of this method of repair.

Coaxial Construction Ignitrons

Two ignitron rectifiers to handle short-duration, high-voltage pulses in welding duty are announced by Associated Electrical Industries, Ltd., Electronic Apparatus Division, Lincoln. The rectifiers, BK300B and BK302B, are of a new coaxial construction in which the current flows through the ignitron from anode to cathode and then up the valve wall to a cathode flange terminal at the top. This coaxial current flow provides a magnetic shield to eliminate the arc deflection which the high peak currents might cause in ignitrons of conventional form. The ignitrons are water-cooled and can be supplied with the usual form of thermostat for over-temperature protection. Both are provisionally rated for 2500V maximum peak anode voltage. The BK300B, which is equivalent to the American GL7670, has provisional anode current ratings of 2000A peak, 10A mean, and the BK302B has twice these ratings.

[Reply Card No. 1198]

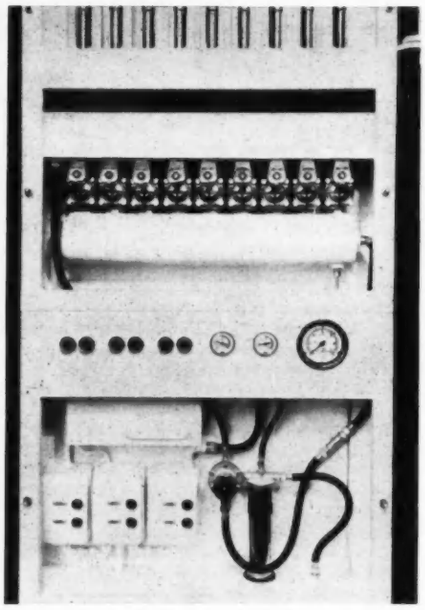
Helical aerials with tracking equipment for guided missile training

SHORTER REPORTS *(Continued)*

Automatic Continuously-Rated Dust Collector

A CONTINUOUSLY-RATED air filtering equipment designed to give efficient service over an extended period, has been introduced by Dallow Lambert, Ltd., Thurmaston, Leicester. This " Dalamatic " automatic fabric filter is stated to have been tested in a variety of industrial applications and the results obtained to indicate that it is suitable for almost universal application. The filter employs limited quantities of compressed air as a cleaning medium, but it has no mechanical moving parts. The basic design incorporates an integrated system of standard filter units by which there can be assembled installations capable of handling air volumes of the order of 100,000 c.f.m. or more if required.

An installation in simple form may consist of one, two or three tier assemblies mounted on a hopper, a silo pressure vessel or a conveyor to suit the individual application and each tier contains nine pad type filter elements with a fabric area of 60 square feet. In operation, contaminated air is entrained into the filter above the level of filter elements, passes downwards between the elements and is filtered into a common outlet header running the height of the filter. Dust initially retained on the filtering medium is removed in a controlled manner to the hopper below the filter, and is eventually discharged by means of a rotary seal or other conventional method. In applications with a heavy dust or product burden, a primary separator is integrated within the filter hopper, only the fines being circulated through the filter, so avoiding any tendency for fabric abrasion to become a significant factor.



Compressed air control and distribution equipment of compressor

Multi-assemblies of the equipment as shown on this page can be achieved in a side-by-side or back-to-back arrangement, or a combination of both.

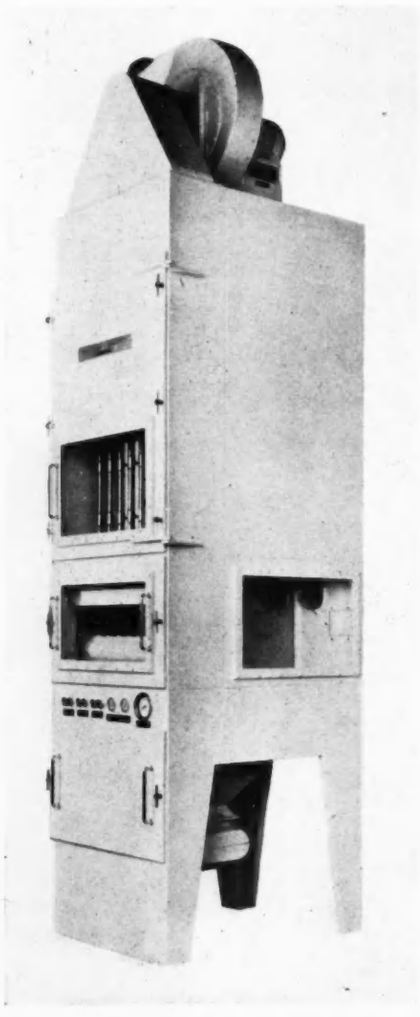
The maximum fabric area of a single unit is obtained by three filter tiers, giving, at present, 180 square feet of fabric ; multi-assemblies increase filtration area accordingly. A single three-tier assembly would have a continuously rated gas throughput, on average, of about 2000 c.f.m., varying from 1000 c.f.m. for dusts with obnoxious filtration characteristics to more than 3000 c.f.m., for dusts with benign behaviour.

The filter elements consist of pad type sleeves fitting over a specially designed matrix and header ; filter media being available in a variety of materials, natural or synthetic, woven or non-woven. The filter elements also act as flow straighteners and exert a significant influence on airflow stability within the filter. The method of assembly used permits pad removal and inspection from the clean side of the filter. Removal of a filter element simply involves the disconnection of the relevant compressed air distribution pipe by loosening one standard pipe union, followed by the release of the two filter element securing nuts.

The control of pressure drop caused by the deposition of collected dust on the filter medium is exercised by subjecting each vertical row of filtering elements to a concatenated cleaning cycle. Specially designed nozzles from high-pressure air distribution lines extending over the filter element outlets deliver blasts of high-pressure air into the filter elements in controlled sequence. Each air blast effects a momentary reversal of filtered air flow which, allied with a measured shock wave to the fabric element, dislodges the deposited dust, to fall to the hopper below. The duration of compressed air delivery is of such limited duration as to avoid significant diminution in main air throughput. Control of compressed air delivery is effected by solenoid valves activated by a variable electrical impulse controller, different frequencies being used to suit different dust characteristics.

In the variable electrical impulse controller a small constant speed motor drives a multi-cam assembly through a series of reduction gears and, by the sequenced operation of micro-switches, activates the solenoid valves in turn.

[Reply Card No. 1197]



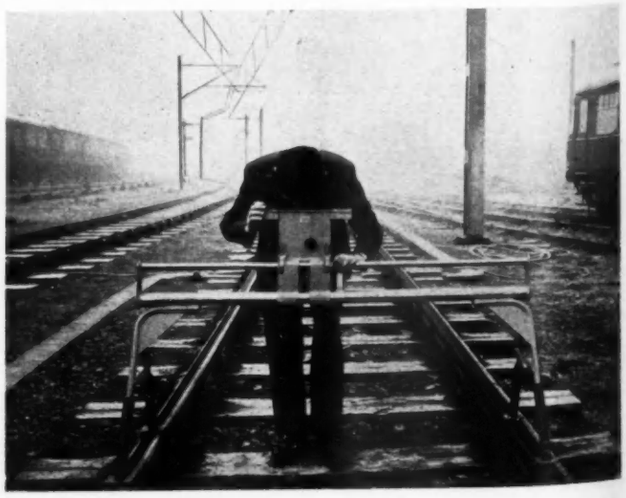
Automatic fabric filter ; with exhaust fan, rotary dust discharge valve and instrumentation

Checking Railway Catenaries

OVERHEAD supply systems on electrified railways can be checked without switching off power by means of the height and stagger gauge illustrated. This device, produced by Barr and Stroud, Ltd., 1, Kinnaird House, Pall Mall East, London, S.W.1, shows by optical measurement the height of the contact wire and its offset relative to the track, the offset being varied in a regular cycle in order to distribute wear evenly over the contact surfaces of pantographs. The instrument is now in service with several regions of British Railways, who were responsible for evaluating the prototype. The design is such that instruments can be made for any wire height or track gauge likely to be found in practice, and accuracy of measurement is stated to be within about ¼in to ½in under normal conditions.

The height and stagger gauge is mounted on the calibrated horizontal bar of a light alloy stand which rests on the rails. The operator looks down into an eyepiece and sees two images of the overhead cable in the upper and lower halves of the field of view. Height is measured by turning a calibrated knob until the two images are in coincidence. Stagger, or horizontal position, is measured by sliding the instrument along the bar to align the images with a reference mark in the field of view. Although designed for use on railways, the gauge with a suitable stand can be used whenever the height of a cable or structure with a straight horizontal edge is to be measured. The normal range of 13ft to 20ft could be modified slightly if required.

[Reply Card No. 1195]



Measuring the height and offset of a high-voltage contact wire relative to the railway track

Counters for Neutron Flux Measurement

A SERIES of proportional counters (PNI 1077), developed for use at low power lever levels in the neutron flux measuring channels of nuclear reactors, has been introduced by Plessey Nucleonics, Ltd., Weedon Road, Northampton. To make the counters suitable for immediate operation after long periods of irradiation in high neutron fluxes, the tubular body is of high-purity aluminium (containing 1·25 per cent magnesium) with an internal coating of 94-per-cent-enriched boron and an inert gas filling. The ceramic-to-metal seals and ceramic insulators are designed to be sufficiently robust for use on industrial plants. The anode is a stainless steel wire of 0·003in diameter. The counter operates at relatively low voltages and a gas multiplication of fifty is obtained at about 750V but higher gas multiplication may be used if required.

Irradiation of the counter in a high neutron flux activates the counter body and produces a background count similar to that obtained in high gamma fluxes, which may be rejected by operating the counter at an e.h.t. value below that at which the pile up of residual activity and gamma pulses is sufficient to pass the discriminator threshold chosen. In practice after long irradiation in a thermal flux (*nv*) of 10^{10} this background can be rejected within ten minutes of the removal of the neutron flux. In most cases therefore where the counter is used for the low level neutron flux instrumentation of a reactor, no retraction mechanism is necessary to remove the counter once full power is reached.

The counter is also very resistant to long term radiation damage since, unlike BF_3, the counting gas is not affected by irradiation and the counting characteristics remain unchanged over a total dose (*nvt*) of more than 10^{18}.

Technical Particulars of PNI 1077 Proportional Counters

Operating limitations :	
Maximum e.h.t. voltage ...	1200V
Temperature...	70 deg. Cent.
Neutron flux (*nv*)	10^{10}
Total neutron dose (*nvt*) ...	$>10^{18}$
Total gamma dose	5×10^{8} rads
Operating characteristics :	
Voltage...	750V
Charge per pulse...	2×10^{-14} coulombs
Plateau slope	0·12 per cent volt

	PNI 1077/9	PNI 1077/6	PNI 1077/3
Sensitivity (*c*/*nvt*)... ...	9	6	3
Dimensions :			
Diameter (in)	1	1	1
Length of sensitive volume (in)	24	16	8
Overall length (in) ...	30¼	22¼	14¼
Weight (g)	303	240	186

[Reply Card No. 1188]

Portable Emergency Light

AUTOMATIC emergency lighting immediately on occurrence of a mains failure is provided by the "Exide Keepalite" "P" unit introduced by Chloride Batteries, Ltd., Exide Works, Clifton Junction, Manchester.

Battery-operated lamp and trickle-charger for automatic emergency lighting

When plugged into an ordinary power point, the battery in the unit is kept ready for service by trickle charging, and if the mains supply fails is connected automatically to the 36W lamp in the swivel-mounted lighting fitting seen in the illustration. The unit is self-contained in a sheet steel container, with battery and charger housed in separate compartments. An on/off switch is mounted on the front and the unit is normally left connected to the mains supply, a small neon indicator lamp showing that the supply is healthy. With a 36W bulb, 3½ hours' emergency light is provided, or 1½ hours' standby lighting when two bulbs (not exceeding 60W in all) are used.

The "Exide" battery, designed for use on trickle charge, comprises a 12V assembly of two 6V 3CB5 units, each with a capacity of 12·5Ah at the ten hour rate. Each battery is assembled in a three-compartment container moulded in translucent polystyrene. At average room temperature topping up is necessary only two or three times per year. The equipment weighs only 30 lb complete and measures 4¾in wide by 13in long by 14¾in high (including height of lamp).

[Reply Card No. 1196]

Air Line Filter and Lubricator

A COMPRESSED air filter incorporating an automatic drain device and an air line lubricator now available from Doulton Industrial Porcelains, Ltd., Wilnecots, Tamworth, Staffs, are illustrated below. The "Auto-drain" filter operates on the same principles as the maker's compressed air filter introduced last year. In addition to a multi-stage cleaning action to remove all impurities, both solid and liquid, from the air stream, the filter has an extended body which accommodates the float portion and pilot-valve of the automatic drain mechanism. The drain section is contained within a small casing attached to the bottom of the filter body, and it comes into operation when the accumulation of liquid in the sump causes the float to lift and open a small pilot-valve. This pilot-valve, at the uppermost end of a small bore tube is always above liquid level and this, together with the fact that only very small volumes of air pass through the valve in normal use, means that the valve mechanism cannot become blocked.

Compressed air filter incorporating automatic drain device with air line lubricator attached

In the draining operation, the opening of the pilot-valve admits compressed air to a pilot chamber where it actuates a synthetic rubber diaphragm to open the main scavenger valve, draining the unit. As the float then drops and the pilot-valve is closed, the main scavenger valve remains open for a sufficient period, as determined by an atmospheric bleed in the pilot chamber, to permit complete drainage of the sump. Provision is made also for manual draining by depression of a push-button control on the casing.

The air line lubricator can be adjusted over wide limits to determine the amount of oil mist introduced into the compressed air system and gives visual indication of the oiling rate since all oil which passes through the sight glass is atomised and delivered into the air line. A non-return valve in the oil supply line between reservoir and atomising zone ensures oil injection immediately air flow starts after any period of shut-down. A small venturi section gives high air velocities at the point where oil is injected and ensures enduring atomisation at air flow rates of less than 1 c.f.m. A by-pass valve which is fitted comes into operation as the air flow rates increase, by-passing a proportion of the air and ensuring continued lubrication at high rates of flow with minimum pressure drop. The compressed air filter and pressure regulator have line connections screwed ¼in B.S.P.

[Reply Card No. 1186]

Non-Aqueous Phosphating

THE Paints Division of Imperial Chemical Industries, Ltd., has introduced "Kephos," a non-aqueous phosphating process which dispenses with rinsing and tank heating, forms no sludge, and produces a sealed phosphate coating. "Kephos" contains a sealer which is sufficiently corrosion resistant to protect work during transport or temporary exterior storage for up to a week, or indoor storage up to six months. Under normal production conditions work can be welded through the Kephos film. This enables such things as box sections to receive some protection internally. Phosphating by the process is not confined to dipping; the coating may be applied by brush, roller, spray or flow-coating, the most suitable method depending on the characteristics and number of articles to be coated. It can be used to supplement existing phosphating facilities when an article is too large for the plant, or when the volume of work is abnormal. For regular use the higher chemical cost of "Kephos" is offset, it is claimed, by the compactness and simplicity of plant requirements and the saving in heating and maintenance costs. The ideal arrangement is to degrease the work and apply "Kephos" before it is put in store. It is then protected until it has to be painted, and all that is necessary to prepare it for painting is to remove surface dirt.

[Reply Card No. E1215]

Pipe and Pipeline Convention

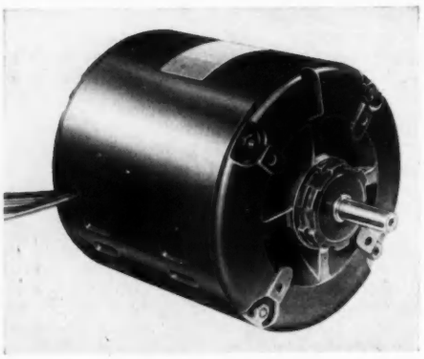
IN conjunction with the Pipes, Pipelines, Pumps and Valves Exhibition to be held at Earls Court on April 9 to 13, 1962, it is intended to hold a Technical Convention. A Convention Committee has been formed under the chairmanship of Sir Harold Hartley and the Convention, which will last four days, will be divided into sessions each concerned with a particular theme as follows :

"Piplines in the modern world. Their scope, future and legislative control"; "Manufacture, construction and maintenance of steel and cast iron pipe and pipelines"; "Manufacture, construction and maintenance of other types of pipe and pipelines (non-ferrous, concrete, glass fibre, plastic, pitch fibre, &c.)"; "Operation and economics of oil pipelines, including product pipelines and L.P.G."; "Operation and economics of gas pipelines, including underground storage"; "Pipelines for other uses : (water, sewage, steam, &c.)"; "Specialised piping systems for chemicals, nuclear power, the conveyance of solids"; "Instrumentation and automatic control of pipelines"; and "Submarine pipelines."

SHORTER REPORTS *(Continued)*

Fractional Horsepower Motors

FOUR main categories of motor comprise the T30 range of single-phase fractional horsepower units introduced by Crompton Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2. These are : (*a*) shaded pole ; (*b*) capacitor-start induction-run ; (*c*) capacitor-start and run ; and (*d*) split-phase start. All are available with drip proof enclosure, and the shaded pole motor can be supplied in totally-enclosed airstream and totally-enclosed still air ratings. The range is available in ratings from $^1/_{40}$ h.p. at 1350 r.p.m. as a shaded pole, totally-enclosed, still-air motor, and up to $\frac{1}{8}$ h.p. at 1425 r.p.m. as a drip proof split phase or capacitor motor. Suitable applications include drives for office appliances such as calculating machines, computers and duplicators ; for fan drives in air-conditioning plant, cooler units, unit heaters, small workshop appliances and laboratory equipment. All-angle mounting methods available are resilient base, resilient rings without base, endshield pad with tapped holes (illustrated) and endshield pad with extended studs. Motors with a resilient base have a centre height of $2\frac{3}{8}$in.



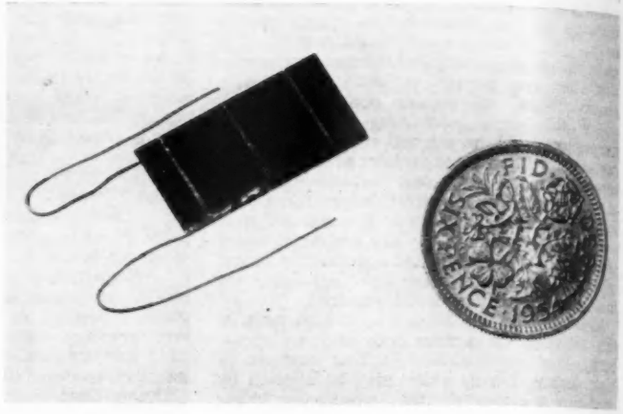
Endshield-mounting fractional horsepower motor with tapped holes in pad

In order to comply with N.E.M.A. standards, the motors have a $\frac{3}{8}$in diameter shaft extension. Bearings, however, allow for $\frac{1}{2}$in diameter shafts to be provided at either end of the machine for small extra cost. The oil wells contain enough oil when charged for two years' running at normal ambient temperatures and hours of operation. The oil cannot be spilt, being absorbed in a felt developed specially for this purpose, which supplies a free flow of filtered oil to the bearings. The split-phase and capacitor-start induction-run motors employ a separate starting relay which is suitable for all-angle mounting. Capacitors for capacitor-start, induction-run and capacitor-start and run motors are also separately mounted. Loose lead connections are brought out through the shell at the non-driving end. Rotors are pressure die-cast and "steam-blued" to reduce losses. Large fins for heat dissipation from the rotors act as fans to cool the stator windings. Stator windings are insulated with polyvinyl acetyl resin.

[Reply Card No. 1194]

Silicon Photovoltaic Cells

To provide power for the communication systems of earth satellites, the Caswell Research Laboratories of The Plessey Company, Ltd., Ilford, Essex, are developing silicon photovoltaic cells which under ideal load conditions have a high conversion efficiency up to $12\frac{1}{2}$ per cent. Work at present in hand includes a development contract for the Ministry of Aviation. Two basic manufacturing configurations are being examined —the diffusion of phosphorus and the diffusion of boron—and techniques are being developed to ensure low internal resistance. One of the cells is illustrated herewith. Among the environmental conditions affecting the efficiency of silicon photocells, temperature is one of the most important. The effect of increasing temperature is to decrease, not increase, conversion efficiency. For space applications some method of stabilising the temperature of the cells must be used, and a current method is to coat the surface of the cells with selective transmitting or reflective coatings so that only useful radiant energy is absorbed.



Silicon photovoltaic cell developed for satellite applications

In addition to providing power, solar cells may be used in earth satellites to detect the impact of very small meteorites or micrometeorites encountered in space. Sunlight passing through holes made in a thin metallic film by the micrometeorites will fall on solar cells and signals from the cells will indicate the number and size of the holes. It is expected that by this means holes formed by particles down to 1 microinch in diameter will be detected.

[Reply Card No. 1181]

Propane Gas Point Heater for B.R.

To prevent the time delays to trains caused by points becoming frozen or blocked by snow in winter the North Eastern Region of British Railways is to install 586 point heaters at important junctions on the East Coast main line. As an outcome of experiments carried out last winter there has been developed a point heating equipment which is easily fitted to the rails and effective in melting snow and ice.

The equipment, illustrated below, comprises two similar assemblies, each consisting of a gas and air mixer unit connected to 1in galvanised pipe to which are fitted five radiant elements facing into the web of the stock rail, one to each of the first five bays behind the switch toe. Normally, the mixer is fitted at the opposite end to the point toe and the assembly is held by coach screw clamps on the sleeper ends. Both mixers are coupled by $\frac{1}{2}$in P.V.C. piping from a common feed and carry propane at a pressure of 14·7 lb per square inch. A shield fitted over the mixer collects warm air from the first element to increase burning efficiency.

Propane gas point heater being fitted to rail

A Dutch firm has developed the radiant element which is incorporated in these "Mills-Arma" switch heaters, which are manufactured by James Mills and Exors., Ltd., Stockport. The mixed gas ignites in front of a ceramic honeycomb block which, as it warms, moves the combustion area back into the block itself, thus providing a source of infra-red heat and forming a screen to prevent the burning gas from being blown out.

To feed the point heaters on the lines north of York, a 5-ton capacity storage tank has already been installed at the Motive Power Depot, while other tanks of 5-ton and 2-ton capacity are planned to feed the point heaters to the south. Bulk storage tanks of 10-ton capacity will feed the point heaters at Darlington and Newcastle. Prior to the installation of these heaters, severe weather conditions in York alone could lead to some 200 to 240 men being taken off other work and employed in shifts, day and night, throughout the period of the emergency. With the gas heaters, twenty-four men will be needed and what is more important, all the points will be kept continually clear and free-moving. It is expected that all the new heaters will be installed before the onset of wintry conditions this year.

Launches and Trial Trips

CLYMENE, oil tanker ; built by Hawthorn Leslie (Shipbuilders), Ltd., for the Hadley Shipping Company, Ltd.; length overall 560ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,500 tons ; thirty-three cargo oil tanks, one main cargo pump room, four vertical centrifugal turbopumps, two stripping pumps ; two 400kW turbo-alternators ; one set of Hawthorn Leslie double-reduction geared turbines, 7500 maximum s.h.p., two Foster Wheeler E.S.D. boilers supply steam at 525 lb per square inch and 850 deg. Fah. Trial, July 6.

POLE STAR, lighthouse tender ; built by The Caledon Shipbuilding and Engineering Company, Ltd., for the Commissioners of Northern Lighthouses ; length between perpendiculars 215ft, breadth moulded 40ft, depth moulded 18ft 6in, service draught 12ft 9in, speed $14\frac{1}{2}$ knots ; forward hold for stowage of large buoys, afterhold and 'tween deck for stores, one 15-ton, one 6-ton and two 3-ton derricks ; three 90kW diesel-driven generators, two six-cylinder "Polar" two-cycle, single-acting, diesel engines, each developing 960 b.h.p. at 250 r.p.m. Trial, July 13.

LEVERNBANK, cargo ship ; built at Belfast by Harland and Wolff, Ltd., for Andrew Weir and Co., Ltd.; length between perpendiculars 450ft, breadth moulded 62ft 6in, depth moulded to upper deck 38ft 6in, gross tonnage 6300 open shelter, 8700 closed shelter ; five main holds, one 25-ton, four 10-ton, ten 5-ton and two 3-ton derricks, fourteen electric winches ; three 175kW diesel-driven generators ; Harland and Wolff two-stroke, single-acting, opposed piston oil engine, six cylinders 620mm bore by 1870mm combined stroke. Trial, August 18.

INDUSTRIAL NEWS

Merger of Unions

At a joint meeting, held under the auspices of the T.U.C., between the executives of the Boilermakers' Society and the Ship Constructors' and Shipwrights' Association last week, a statement was issued which said that the executives were firmly convinced that it would be in the best interests of their respective members and the shipbuilding industry that the amalgamation of the two unions should be effected in the near future. The two executives agreed to take an early vote of their members on proposals for the amalgamation which had been unanimously agreed, and also agreed to recommend their members to vote for their adoption.

Broadly speaking, the statement says, the proposals provide that both shipwrights and boilermakers would have full autonomy to deal with matters concerning their own particular trade. Each section of the amalgamated union would elect its own officials and control its own trade procedure. So far as work was concerned in the shipyards the amalgamation would provide that if members of either section were not available because of shortage of labour, interchangeability between the sections would apply. The ratio of shipwrights to boilermakers would be maintained on a yard-to-yard basis on assembly, erection and fairing irrespective of the location of work in the yard, and this ratio would be that which was in operation in each yard as at October, 1959, either on the basis of combined teams or other methods, on the same ratio acceptable to both sections within the respective shipyards. Alternatively, if the present practices were acceptable to both unions then these would continue.

In the case of H.M. dockyards, the statement continues, the general executive committee of the amalgamated union would undertake to maintain existing practices as regards present members of the Shipwrights' Association and the Boilermakers' Society. On the subject of demarcation generally, the statement adds, any difficulties which might arise between the shipwrights' and the boilermakers' sections which could not be settled internally within the district would be settled by local arbitration.

Further Trading Opportunities in Europe

The Export Council for Europe's third report, published this week, describes market opportunities in Belgium and Luxembourg, Finland, Greece, Ireland, the Netherlands and Turkey. Present opportunities for the export of British capital goods are not limited to countries now substituting industrial for traditionally agricultural economies, the report says, though these are among the most obvious. In all the seven European markets considered the report suggests that there are openings for British firms, although attention to price, design and delivery, and consideration of credit conditions where these apply, may make the difference between sales and disappointment.

The report goes on to draw attention to particular markets which might successfully be tackled by British industry. In Holland, it points out, demand for machine tools is so great that Dutch firms are buying from Eastern Europe, notwithstanding frequently inferior quality and a deficient after-sales service. Belgium's large scale industrial re-equipment programme offers openings for Britain, the report suggests, provided delivery times can at least match those of West Germany, which have lately tended to lengthen. Sales of specialised plant, with provision of technical skill, by British firms willing to operate as sub-contractors or licensees to Belgian industry, could be increased. Finland now needs plant and equipment, the report states, for the redevelopment of the Porkkala enclave. Besides immediate requirements, including harbour reconstruction for this potentially productive area on Finland's Baltic coast, there are needs for rolling mill plants, textile machinery, steel ship fitments and knitting machinery. Raw materials and capital equipment including agricultural machinery are required in Turkey. In their struggle to modernise their economies, the report adds, both Greece and Turkey have immediate basic needs, ranging from excavators and road-making machinery, to canning and freezing plants, tin plate and steel. Greece requires cranes and loading gear for the enlargement of Piraeus harbour, the report says, and specialised equipment as surveys of mineral deposits disclose prospects of profitable mining. Extensive Greek power station projects, and transport and agriculture development also provide openings. The Greek Industrial Development Corporation is seeking British participation, the report states, in its project to produce between 250,000 and 300,000 tons of steel annually. Britain has been losing ground to Continental competitors in Ireland largely because of price differentials, the report says, but an effort to regain this lead, especially in respect of printing and agricultural machinery, and weaving looms, would be well worth while.

Overseas Trade

The monthly figures issued by the Board of Trade show that United Kingdom exports in August were valued at £305,200,000, imports at £358,800,000, and re-exports at £13,400,000. The rate of export in the first eight months of the year was 4½ per cent more than the average for the year 1960, although if ships are excluded, the increase was 3 per cent. There has been no evidence, the Board says, of any upward or downward movement in the underlying trend of exports since the beginning of the year.

Most of the increase in exports compared with earlier in the year was in exports of manufactured goods, and, in particular, ships. There was also an increase in exports of aircraft and exports of metals and miscellaneous metal manufacturers were slightly up. Exports of other engineering products showed little change. Exports in the last three months included some goods delayed in May by the dock strike, and to avoid this distortion the figures for the last four months, May to August, are compared with those for the previous three months. Exports of machinery and instruments were little changed, the Board States, but were 17 per cent more than in the corresponding months of 1960. Exports of non-electric machinery were also 17 per cent more than a year earlier. Above average increases on a year ago were shown in exports of boilers and boiler-house plant, excavating and and earthmoving machinery, textile machinery, mining machinery and paper and pulp machinery. Exports of office machinery and of printing machinery, which had earlier been rising strongly, were slightly less than a year earlier. Exports of tractors showed a rather larger increase in the last four months on a year earlier than in the previous months. Exports of electric machinery and apparatus were 16 per cent more than a year ago, and exports of scientific instruments were 17 per cent more than a year earlier. Exports of road vehicles, seasonally adjusted, fell further, by 5 per cent, the Board says, between February-April and May-August.

Accidents in Industry

The British Safety Council, in a new approach to accident prevention in industry, is planning a nationwide series of training courses directed at foremen. The courses will last for four half days and each will be followed by an examination. Commenting on the 25 per cent increase in accidents to young workers over the past two years, Mr. Leonard Hodge, the Council's national director, said that this would suggest that present methods of accident prevention in factories were ineffective. The Council believed the foreman was the key figure in accident prevention, he added; he was on the shop floor all day long and could see where the faults lay and could talk more easily to the young workers. Courses will be held in most major cities, but the Council is prepared to hold them anywhere in the country, Mr. Hodge said, where it could get thirty foremen together.

The Council believes that by taking safety to industry in this way, managements will be more willing to co-operate than if the courses were held centrally. So far, the Council states, safety training has been in the form of written instruction, and as the figures illustrate—26,000 young workers injured in the last two years—this has had insufficient effect.

University Scholarships

The Electricity Council announces that in order to enable the electricity supply industry to meet its future requirements for top-level scientists and engineers the industry is currently offering sixty-one university scholarships to outstanding school-leavers. The scholarships provide for the payment of all tuition and other university fees, plus a maintenance grant of £375 a year at Oxford and Cambridge, £360 a year at London and £330 a year at other universities. Both boys and girls, aged from seventeen to twenty-one, who wish to become scientists or engineers, are eligible to apply. Thirty-six scholarships, all in electrical engineering, are offered by the combined twelve Area Electricity Boards, and twenty-five scholarships, in a wide range of science and engineering subjects, by the Central Electricity Generating Board.

PERSONAL AND BUSINESS

Appointments

BRITISH HOIST AND CRANE COMPANY, Ltd., announces the appointment of Mr. D. L. O. Lloyd as crane sales manager.

MR. R. H. HOGARTH has been appointed group publicity manager to the Teddington Group of Companies, Sunbury-on-Thames.

CAPTAIN MAURICE LUBY, RN(Retd.), M.I.Mech.E., F.R.Ae.S., has been appointed research director of High Duty Alloys, Ltd., a company in the Hawker Siddeley Group.

MR. R. I. DOUGLAS has been appointed export sales manager of Permali, Ltd., Gloucester. He will continue to be responsible for the sale of track insulation, &c., to British Railways.

MR. FREDERICK THOMAS JONES, A.M.I.Prod.E., has been appointed a director, and MR. JOHN ARTHUR GRACE, commercial director of Microcell, Ltd., a subsidiary of B.T.R. Industries, Ltd.

MR. R. W. JELBART, of R. B. Pullin and Co., Ltd., has been appointed sales manager to the traffic barrier division of the company. This appointment is in addition to the position he already holds as sales manager to the thermostat division.

MR. FRED COX has resigned his position as deputy manager of Newton Chambers Foundries, Chapeltown, near Sheffield, to join the John Vickers and Sons, Ltd., group, of Darlington, as general foundry manager of Newgate Foundry, Barnard Castle, Co. Durham.

THE MINISTRY OF TRANSPORT states that Mr. H. Perring has been appointed to succeed Mr. R. A. Lovell, A.M.I.Mech.E., as chief mechanical engineer. Mr. Lovell will retire next December and Mr. Perring will take up his new appointment at the beginning of that month.

MR. LEONARD H. SHORT, director of overseas operations, the English Electric Company, Ltd., has been elected chairman of the export panel of the British Electrical and Allied Manufacturers' Association in succession to Mr. E. V. Small. The new vice-chairman is Mr. Harold P. Martin, sales director of C. A. Parsons and Co., Ltd.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., has announced the following engineering appointments in its turbine-generator division: Mr. J. S. Hall, A.M.I.Mech.E., divisional assistant chief mechanical engineer (turbines); Mr. J. V. Bigg, A.M.I.Mech.E., A.M.I.Mar.E., divisional assistant chief mechanical engineer (auxiliary apparatus) and chief engineer, general engineering department; Mr. D. M. Smith, M.I.Mech.E., F.R.Ae.S., consulting mechanical engineer; Dr. D. F. Shannon, M.I.Mech.E., chief engineer, mechanical experimental development and gearing; Mr. F. R. Harris, A.M.I.Mech.E., chief engineer, advance turbine development and chief engineer, gas turbine engineering department; Mr. J. C. London, M.I.Mech.E., A.M.I.C.E., chief engineer, large steam turbines; Mr. A. A. Garson, A.M.I.Mech.E., chief engineer, medium steam turbines.

BRITISH AIRCRAFT CORPORATION, Ltd., announces the following new appointments which will become effective on October 1, 1961: Sir George Edwards, Hon.F.R.Ae.S., Hon.F.I.A.S., executive director, aircraft, is appointed managing director of British Aircraft Corporation, Ltd. He will cease to be managing director of Vickers-Armstrongs (Aircraft), Ltd., and will become deputy chairman of that company. The Rt. Hon. Viscount Caldecote, M.I.Mech.E., M.I.E.E., A.F.R.Ae.S., executive director, guided weapons, is appointed deputy managing director and chief executive, guided weapons, of British Aircraft Corporation, Ltd. Marshal of the Royal Air Force Sir Dermot Boyle has been appointed to undertake special responsibility for co-ordinating the administration of personnel and training and education within the group. Mr. A. W. F. Houghton, A.F.R.Ae.S., is to be managing director of Vickers-Armstrongs (Aircraft), Ltd.

Business Announcements

ALLIS-CHALMERS GREAT BRITAIN, Ltd., announces the acquisition of Jones Balers, Ltd., Mold, North Wales, which will operate as a wholly owned subsidiary.

NORTON GRINDING WHEEL COMPANY, Ltd., Welwyn Garden City, Herts., states that as from October 2, 1961, the address of its Manchester office and warehouse will be Wharf Road, Sale, Cheshire (telephone, Sale 8285/7).

JOHN GOSHERON AND CO., Ltd., has moved to larger premises at the Packaging and Industrial Tape Centre, 58-60, Kensington Church Street, London, W.8 (telephone, Western 8011).

ALLIED IRONFOUNDERS, Ltd., has announced that three of its sales divisions—the domestic appliance division, the bath division and the electrical appliance division—have moved into a new building in Cadbury Road, Sunbury-on-Thames, Middlesex.

FORD MOTOR COMPANY, Ltd., tractor group, announces a new automatic pick-up hitch as optional equipment for its "Super Major" tractors. Operating independently of the three point linkage, it enables the tractor driver to change from working mounted implements to trailers without dismounting from the tractor.

RESEARCH AND CONTROL INSTRUMENTS, Ltd., King's Cross, London, W.C.1, and SONATEST, Ltd., London, W.C.1, have signed an agreement to the effect that marketing in the United Kingdom of Sonatest ultrasonic non-destructive testing equipment will be carried out exclusively by Research and Control Instruments, Ltd.

THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS announces that the secretary, Mr T. S. Nicol will retire on January 31, 1962, and that, his successor will be Commander R. F. A. Whately M.A., R.N., who will enter the Institution's service in October as deputy secretary and will take office as secretary on February 1, 1962.

THE IRAANSE AARDOLIE EXPLORATIE EN PRODUCTIE MAATSCHAPPIJ (Iranian Oil Exploration and Producing Company), N.V., has begun drilling an oil well at Khalafabad, 15 miles south-west of the prolific Agha Jari field. The well, KD-1, was spudded in on September 8. The company had produced 38,000,000 tons of crude oil by the end of August this year, and increase of 18 per cent compared with the same period last year.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., has started production of "Ulstron"—its new high-tenacity polypropylene filament yarn—on a pilot plant at the company's Wilton Works in North Yorkshire. The first full-scale plant, with a capacity of 5,000,000 lb per annum, will commence production at Wilton by the end of the year, and extensions will be built as required at the company's new site at Kilroot, in Northern Ireland.

MR. F. L. GRIFFITHS, M.Inst.F., M.I.Plant.E., has relinquished his post as works engineer of the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd., at Erith, upon his appointment as constructional engineer for the whole of the G.E.C. organisation. He is replacing Mr. R. Bennett who is retiring from the company's service, and from September 1 will be located at Wembley. His successor as works engineer at Erith is Mr. H. B. Pellatt.

TURNER AND NEWALL, Ltd., announces that following the death of Mr. C. H. Glassey, the former chairman of British Industrial Plastics, Ltd., Mr. R. M. Bateman has been appointed chairman of that company. Mr. Bateman, who is deputy chairman of Turner and Newall, Ltd., was appointed to the board of British Industrial Plastics, Ltd., in May, 1961. Dr. W. Blakey, a joint managing director of British Industrial Plastics, Ltd., has been appointed deputy chairman of that company.

BURMEISTER AND WAIN announces the formation of a new subsidiary company, Burmeister and Wain (Great Britain), Ltd., with offices at 115, Leadenhall Street, London, E.C.3. Mr. Jorgen Berring has been appointed London manager, and the new company will represent the parent company in all activities in Great Britain. It will provide liaison with the sole British licensees, Harland and Wolff, Ltd., and its sub-licensees, John G. Kincaid and Co., Ltd., and facilitate co-operation and exchange of information as an aid to development.

JOSEPH SANKEY AND SONS, Ltd., announces that Mr. H. F. Hodgson, having reached normal retirement age, is retiring on September 30, 1961, from his appointments as chairman and as managing director of the company. He will continue as a director of the company. Mr. R. P. Brookes, a director of the parent company, Guest, Keen and Nettlefolds, Ltd., has been appointed chairman of the company with effect from October 1, 1961. Mr. G. B. Sankey, at present assistant managing director, has been appointed managing director, also with effect from October 1, 1961. Mr. Hodgson is continuing as a director of Guest, Keen and Nettlefolds, Ltd., and on the boards of a number of G.K.N. Group Companies.

AVDEL, Ltd. (formerly Aviation Developments, Ltd.) has opened a new factory at Welwyn Garden City, Herts, to provide the additional space required to increase production of its range of high-speed fastening devices and equipment. This factory has a productive floor area of 76,000 square feet and offices covering a further 16,000 square feet, and its opening has enabled the whole of the firm's production to be concentrated under one roof with room for future extensions. The products now in full production include the "Avdel" self-sealing blind riveting equipment; "Chobert" rapid riveting sets and rivets; "Jo-bolt" high strength blind fasteners; "Pip" positive lock quick release pins; riveting clamps; "Huckbolt" high-speed fasteners for sheets, &c.

Contracts

ALEXANDER STEPHEN AND SONS, Ltd., has received a contract from the British Transport Commission to build a 7000-ton, twin-screw, geared turbine passenger ship having a length of 404ft by 57ft 6in beam and service speed of 21 knots. The ship, which will operate on the night service between Harwich and the Hook of Holland, will carry 750 passengers, of whom 600 will be berthed in 280 cabins.

THE GENERAL ELECTRIC COMPANY, Ltd., has received from the Central Electricity Generating Board, an order, worth about £360,000, for two 60MVA synchronous condensers which are the largest machines of this kind ordered for service in Great Britain. The synchronous condensers are to be installed in the Fleet substation, near Aldershot, where they will be used to provide power-factor correction and voltage regulation for the 275kV supergrid. Both machines will be hydrogen-cooled and will be transportable with a maximum weight of 110 tons. They will operate from a 13kV supply and will provide an output variable over a voltage range of +15 per cent to −10 per cent when running at 1000 r.p.m. The plant is scheduled to be in operation in 1963.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., has received an order from the British Broadcasting Corporation for four 250kW short-wave transmitters, forming part of a re-equipment programme for B.B.C. External Services transmitting stations. Two will be installed at Daventry and two at Rampisham, Dorset. The transmitters will operate on any of the broadcast bands in the frequency range 3·95–26·1 Mc/s with an overall working efficiency of approximately 52 per cent. They are single-channel units with manual wavechanging, which can be carried out in under five minutes. Final modulator and final r.f. stages each use two English Electric BY.1144 vapour-cooled valves in push-pull, giving a carrier output of 250kW. Valves in the penultimate stages are also vapour-cooled. To minimise the possibility of spurious radiation from the transmitters causing interference in other bands, particularly the television bands, the r.f. stages are completely enclosed in screening boxes and harmonic filters are fitted in the output transmission lines. It is expected that these four new transmitters will be brought into service during 1964.

Miscellaneous

AIR INLETS.—A range of adjustable air inlets has been developed by Robertson Thain, Ltd., Ellesmere Port, Cheshire, and is suitable for installation in sheeting, brickwork or glazing. The inlets are of heavy gauge aluminium and are available in widths of 1ft 10in and 3ft 10in and ten standard heights ranging from 4ft to 7ft 9in in 5in increments. Control between fully closed and open positions is positive and the linkage system, which is fully enclosed, incorporates nylon bushes.

SEMICONDUCTOR SLIDE RULE.—A slide rule for rapid selection of the correct peak inverse voltage diode for single or three-phase bridge rectifier circuits is available from the International Rectifier Company (Great Britain), Ltd., Hurst Green, Oxted, Surrey. By setting a scale on the reverse of the slide to the d.c. working voltage, the rule automatically gives r.m.s. input voltage required and the correct p.i.v., including a "built in" safety factor. A second factor on the face gives the minimum p.i.v. that can be employed where all transients are known to be suppressed. The back of the rule has other useful information on ripple factor, a.c. to d.c. current ratios and utility factor.

CONTINENTAL AFFAIRS

by Our Continental Editor

The International Motor Show at Frankfurt

No. I

THE International Motor Show at Frankfurt a.M. which opened on September 21 and continues to October 1 is the fortieth German Motor Show and the sixth organised since the war. The Show, which is being held biennially, is scheduled ahead of the Paris Salon and the London Motor Show, thus providing the first of the three international shop windows which can be seen this autumn. The Show has an entirely international character and gives an excellent opportunity of comparing at first hand the relative merits of the various nations' automobile design, their price, appearance and, particularly, their sales appeal to customers in export markets.

Compared to the 1959 Show the floor space of the various exhibition halls and the open air park has been further increased, and the number of exhibitors has grown to more than 800 (40 per cent more than in 1959). The foreign contingent is very strong, numbering 128 firms, an increase of about 50 per cent, which seems to indicate that, with the gradual lessening of import and currency restrictions the time has come for a more general liberalisation of the motor trade. This, apparently, has been realised by the British motor industry, because out of 46 motor-car producing firms represented at Frankfurt, 15 are British, compared to 9 German, 5 French, 8 Italian, 4 American, 2 Swedish and one each Austria, Holland and Czechoslovakia.

It is well known that the Common Market countries increased their industrial production by 12 per cent last year, almost double the expansion rate for 1959. This compares with a general growth rate in highly industrialised countries of only half of that for 1959, namely 5 per cent against 10 per cent. It is obvious that the German motor industry has well profited from these favourable conditions, and has greatly increased its already very powerful influence on European as well as on overseas export markets, partly at the expense of the British export trade. In this respect the manufacturers have been greatly assisted by the one and only trade union, comprising all workers of the German motor industry irrespective of their particular trade. Generally, relations between the two sides of the industry have been cordial. The union is against restrictive practices and clearly in favour of mechanisation, and it accepts enlightened capitalism, making it hard for irresponsible agitators to foment industrial unrest.

In these circumstances it is not surprising that Germany has not only maintained its leading position as the greatest automobile producing country outside the U.S.A., but also as the largest exporter of motor-cars. The steady growth in production is presented in Table I, showing the German production and export figures for the first six months of this year, compared with those of the two preceding years. The table also shows the corresponding figures of the British motor industry.

It seems remarkable that Germany's car exports to U.S.A. have not been affected to any great extent by the demand for American built compact cars or by the "big" compact cars, the so-called "intermediates."

In view of the general growth of production inside the German motor industry it might appear strange that the Borgward group, the only privately-owned motor manufacturers in Germany, should have been forced to close their works in Bremen in the beginning of this year and to dismiss their total labour force of about 20,000 workers. This failure is mainly due to the fact that in three different factories too many types were built in insufficient numbers; apart from three types of commercial vehicles not less than five different models of motor-cars (Borgward, Lloyd and Goliath), each available in two or three versions, were built, with the result that, out of a total production in 1960 of about 75,000 cars, about 19,000 cars were left unsold by the end of last year. Although the stock of unsold cars has now been reduced by about 50 per cent, the fact remains that Borgward has ceased to be a working concern; after the failure to get other firms interested in taking over the complete plant, the liquidation of Borgward seems to be inevitable, and the firm is not represented this year.

Other firms which have not participated in the general rise of production are the manufacturers of small cars fitted with air-cooled, two-cylinder engines up to about 600 c.c. cylinder capacity. Two of these firms, N.S.U. and Glas (Goggomobil) produced less vehicles in 1960 than in the preceding year, and one firm only, Bayerische Motorenwerke (B.M.W.), by introducing an improved 700 c.c. version of their rear-mounted opposed twin-cylinder car, has been able to raise its production figures for 1960 from 28,000 to 42,000, i.e. above the limit of 30,000 cars per year which seems to be the average figure for these types of vehicles. There is no doubt that, in a country of steadily growing prosperity, most customers who only a few years ago were satisfied with turning from the motor-cycle and the motor scooter to some light four-wheeled vehicle have become more discerning and are now able to afford a "proper" car, the more as the difference in first cost between a miniature car and the cheapest standard car (in Germany the V.W.) is comparatively small.

It is obvious that any noticeable change in the social structure of the markets, especially the increased purchasing potential of customers in Germany and those of her main export spheres, must find its expression in the class, price and size of the cars produced in the last few years. Table II, showing the German production figures for the first six months of this year compared to those of 1960 classified according to the cylinder capacity, proves without any doubt, the general tendency towards the bigger and more powerful car; miniature cars up to 500 c.c. capacity are hardly in demand any more, their production figures now amounting to only 1·6 per cent of the total production of cars, excluding dual-purpose cars. Even the formerly strong class of cars up to 1 litre capacity is losing favour; it accounts for not more than 14 per cent of the total production, although it comprises some popular models as the 750 c.c. D.K.W. "Junior" of Auto Union, the 700 c.c. B.M.W., and the 900 c.c. Lloyd "Arabella."

By far the most popular class is that of cars fitted with engines between 1 litre and 2 litres capacity. Dominating in this category which comprises about 78 per cent of Germany's total car production is the V.W. car with the 1·2-litre air-cooled horizontal opposed engine, further the four-cylinder models of Opel and Ford and, at the upper end of the scale, the 1·9-litre four-cylinder cars of Mercedes. The table, however, does not show a rather significant fact, namely the general tendency of customers to prefer an engine of the bigger capacity, whenever the same type of car is alternatively available with either an engine of 1·5 litres or of 1·7 litres capacity as this is the case of the Opel "Record" and the Ford "Taunus." It appears that the advantages of the bigger engine, the higher torque and the correspondingly better flexibility of the car outweigh the slightly higher fuel consumption and, in countries where the road tax and the obligatory third-party risk insurance are based on the cylinder capacity, the increased cost of these items. Although Ford and Opel are making 1·2-litre engines to be optionally fitted into standard 1·5-litre cars, the demand for such models is rather small; the minimum engine capacity considered suitable for a four/five seater family car is that of at least 1·5 litres. In this connection it is worth mentioning that the trend towards engines of higher cylinder capacity is by no means confined to the class of medium-sized cars; in the last year most manufacturers of

TABLE I—*Production and Exports of Motor-Cars* for the First Six Months of* 1961 *Compared to the Same Period of* 1959 *and* 1960

		1961	Change, per cent	1960	Change, per cent	1959
Germany	Production	1,005,410	+ 9·2	927,020	+26	726,970
	Exports	483,730	+11	433,540	+19	366,030
Great Britain	Production	501,670	−36	798,010	+33	593,770
	Exports	178,890	−51	364,300	+29	282,540

* Including dual-purpose cars.

Production and Exports of Commercial Vehicles† for the First Six Months of 1961

		1961	Change, per cent	1960	Change, per cent	1959
Germany	Production	131,018	+12·5	117,590	+11	107,770
	Exports	65,831	+14	58,220	+4	56,320
Great Britain	Production	249,150	+ 6	235,620	+31·5	176,460
	Exports	93,780	+26	74,120	+19·5	62,780

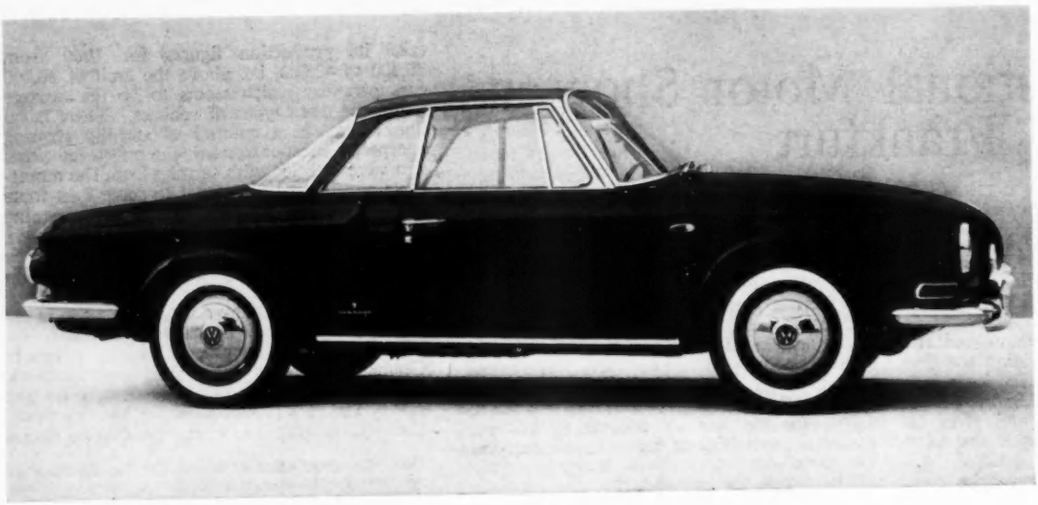
† Including public service vehicles.

TABLE II—*Production of Motor-Cars in Germany for the First Six Months of* 1961 *Compared to the Same Period of* 1960

Motor-cars	1961	Change, per cent	1960
Up to 500 c.c. cylinder capacity	17,910	−11·2	20,180
From 500 c.c. to 1-litre cylinder capacity	136,470	− 9	150,040
From 1-litre to 2-litre cylinder capacity	791,720	+10·2	718,150
Of more than 2-litre cylinder capacity	63,990	+13·9	56,180
Dual-purpose cars	94,440	+ 6·1	91,800
Total...	1,010,090	+ 6·9	944,560

CONTINENTAL AFFAIRS *(Continued)*

Coupé Coachwork at Frankfurt



The new 1500 c.c. Volkswagen, like the original V.W., is available with a Karmann Ghia coupé body; on the larger car there are two occasional seats in the back.

The Fiat 2300 (and 2300S with twin carburetters) is available with a four-seater coupé body originated by Ghia; the standard 2300 has a starkly cuboidal body and quadruple headlamps.

The "Capri" version of the Ford "Consul Classic 315" is structurally identical with the two-door saloon below the waist, but has frameless windows and quarter lights that disappear back and down. Two bucket seats are fitted; a driver of medium height has a good position looking through the top of the screen.

small cars, especially those of the 600 c.c. class (B.M.W., Fiat, Renault and D.A.F.) have been compelled by the demand of customers to increase the capacity of their engines to something between 700 c.c. and 800 c.c.

The class of cars with a cylinder capacity of more than 2 litres accounts for only 6·4 per cent of the total production of cars, excluding dual-purpose cars, and includes the comparatively few six-cylinder types made in Germany, the 2·2-litre and 3-litre Mercedes and the 2·6-litre Opel "Kapitan." It is significant of the increasing number of well-off customers, mainly of the executive and professional classes, that the sales of the six-cylinder Mercedes types last year have gone up by about 80 per cent and those of the Opel "Kapitan" by 90 per cent compared to 1959. The only German car with a 3·2-litre eight-cylinder Vee engine, of either 2·6 litres or 3·2 litres capacity made by B.M.W., is sold in small numbers only.

It is characteristic of the structure of the German motor industry that, after the collapse of the Borgward Group, there are now only four big manufacturing concerns which have, so far, accounted for about 85 per cent of Germany's motor-car production, but will now probably supply 90 per cent of the total demand. They are the Volkswagen Works, with a production last year of 756,000 cars, Opel with 290,000, Ford with 163,000, and the now amalgamated firms of Mercedes and Auto-Union with 248,000 cars. None of these firms makes more than two basic types in large scale production, though small modifications and different types of bodywork such as sunshine roofs, cabriolets or dual-purpose bodies are generally available as long as these do not interfere with the flow of production. A rigid standardisation inside each of these big manufacturing concerns takes care that, as far as possible, the main mechanical components can be machined and assembled on the same transfer conveyors. The limitation to comparatively few types of either 2·6 litres or 3·2 litres especially has certainly lead to an unusual degree of uniformity and even monotony on German roads which seem to be domineered by the familiar shape of the Volkswagen. Apart from this make which actually accounts for every third car now registered in Germany, Opel and Mercedes are the most popular models.

It is remarkable that, with the exception of the four-cylinder models of Opel and Ford, the cars made by the German-owned factories hardly overlap one another in the home market as far as size, general appearance, performance and price are concerned; most of these firms cater for one particular, generally quite clearly defined, group of customers so that mutual competition between firms like Volkswagen or Auto-Union is practically non-existent. Instead of trying to compete in an overcrowded market most of their sales effort is directed towards sales promotion abroad; the small number of different models naturally facilitates the setting up of a competent sales organisation abroad with an efficient service, assisted by an unusually comprehensive stock of spares.

It is obvious that the choice of a car can be difficult for a German customer if he insists on buying a model not included in the limited range of German-built makes. Unless he is content to manifest his non-conformity by some unusual colour scheme (if obtainable), he can and, indeed, does buy a foreign car, preferably a French or Italian one which enjoys the lower tariff of the Common Market countries. Such models mainly include the group of light cars with water-cooled, four-cylinder engines of about 800 c.c. to 1300 c.c. capacity, a class not so easily obtainable among the German-built cars. Popular models in this particular class include the French "Dauphine," the various versions of light Simca cars and, further, the Italian Fiat "600" and Fiat "1100," the two latter cars being assembled in Germany. No small water-cooled sports cars are being manufactured in Germany, and it appears that in this particular line British sports models should be able to compete on favourable terms with the more expensive Italian types, even if handicapped by higher import duties.

Turning now to a general survey of the tendencies evident at the 1961 German motor show we noticed that most of the well-established Continental makes of cars showed no significant changes in their mechanical layout but differed from previous models mainly in improved detail design. There was however, a far greater representation of entirely new types than ever seen before at any of the post-war motor shows. In some cases the main specifications of these cars have already been published in newspapers and trade magazines but making their first public appearance at Frankfurt, these cars were always surrounded by large crowds of interested spectators. Prominent among these technically well-advanced models were such German cars as the Mercedes "300 SE," the "VW 1500" Volkswagen and the new 1·5-litre B.M.W., further such interesting small cars as the French Citroen "Ami 6" and the Renault "R 4," and last but not least, the entirely orthodox, but modified models Fiat "1100"/"1300" and Fiat "1800"/"2300."

By far the most striking changes which immediately catch the eye of the spectator are those concerning the body styling which—last but not least—shows the long awaited and now quite generally appreciated return to sanity. For many years European manufacturers—evidently with an eye on the American export trade—have been copying American fashion tendencies quite indiscriminately, with the result that customers had to put up with such fallacies as front bench seats in European cars, far too narrow to accommodate three people abreast, or excessively curved "panorama" windscreens, necessitating constructionally weak front pillars restricting the door area. Other extravagances of American-inspired styling were the big sweeping tail fins which, in the last decade, had grown from modest timidly beginning sprouting into huge aerodynamic monsters, and the excessive gaudy chromium ornamentation which soon tended to become shoddy. There is no wonder that customers reacted against these chromium-plated caricatures, and it is refreshing to see that such extravagances are now gradually receding or are completely abandoned. Eyes front and rear, having grown from two to four, also seem to slip back again to two; Although some European manufacturers have recently adopted this fashion to suit the styling of a long tapering bonnet, others, like Citreon and the German Ford works prefer rectangular or oval reflectors which produce a road illumination very similar to that of dual head lamps.

The body styling to be seen at Frankfurt is mainly influenced by Italian trends, characterised by a low, almost horizontal roof and moderately curved front and rear windows. The Italian style, sparingly ornamented, may probably look like a squared-off, flat-roofed box with a great expanse of glass, but French and German designers have successfully proved that it is quite possible to revise this style so as to give the boxy rear more grace.

One of the set-backs of American body design which has not been revised yet concerns the seating accommodation. Although there is, among the more expensive cars, a definite tendency towards separately adjustable bucket seats of anatomically correct shape, most manufacturers still maintain the cheaper front bench; in practically all cases, however, the individual back of each seat is well curved to give full support and is separately adjustable.

As far as the mechanical layout of the latest exhibition models is concerned, there is sufficient evidence that the "orthodox" design of a front-mounted engine with rear drive is considered antiquated for cars up to 1-litre cylinder capacity, and indeed no new car of this layout has been produced in Western Europe for the last two decades. It seems likely that either the front wheel drive or the rear-mounted engine will eventually be adopted for cars up to about 1·5 litres or even more litre capacity, the more as the examples of V.W., Citroen, Chevrolet, Porsche and Tatra have shown that either system is quite suitable for cars up to 2·5 litres.

TABLE III—*Car Exports to U.S.A. for the First Six Months of* 1961 *Compared to the Same Period of* 1959 *and* 1960

	1961	Change, per cent	1960	Change, per cent	1959
Germany... ...	101,960	− 4	106,500	− 2	108,420
Great Britain ...	9,430	−89	102,920	− 6	109,400

Apart from the new "V.W.1500," there are no new air-cooled cars at the Frankfurt show; it is feasible that new front wheel-drive or rear-engine cars of 1·5-litre class will be fitted with water-cooled, horizontally-opposed engines or Vee engines, most probably with an aluminium cylinder-block.

There was no noticeable new development as far as engines are concerned; compression ratios between 7·5 : 1 and 8·5 : 1 are quite usual, but it is generally realised that for ordinary carburetter engines a further increase of the compression ratio will not provide any economic advantages. Engine speed, also, has now reached a magnitude which cannot be raised without encountering difficulties arising from high secondary inertia forces, from torsional and bending oscillations, loss of volumetric efficiency and from excessive valve-gear noise. Aluminium cylinder-heads, sometimes with hemispherical combustion chambers, are frequently used in thermally heavy stressed engines, and overhead camshafts are gaining favour. Stiffer crankshafts—now frequently made of sphero-graphite cast iron (a material having a higher damping coefficient than steel) and the increased use of five main bearings in four-cylinder engines (B.M.W., Glas, Fiat, Simca, Alfa Romeo, Volvo) are useful means of dealing with the considerable mechanical stresses of modern high-speed engines.

Fully automatic transmissions are rare in European cars; they are optionally available for some models of more than 2·5-litre cylinder capacity, but, so far, have not become very popular. There is a limited demand for semi-automatic gear-change devices, such as electro-magnetic or hydro-dynamic couplings; here again the demand is not very great, and the only automatic couplings sold in appreciable numbers are some proprietary products with vacuum-operated clutch withdrawal and centrifugal engagement.

Gearboxes have hardly changed since the last Frankfurt Show, but four-speed gearboxes with synchronisation of all forward gears are increasingly used even for cars in the lower price bracket. In cases where three-speed gearboxes are still used, synchronisation of the bottom gear is considered an absolute necessity.

The installation of disc brakes, mostly made under licence of British firms, has made progress, and has almost become universal for heavy cars with sportive character. In case of light, and middle size cars the shoe brake still leads the field; it is maintained that this brake, being lighter and cheaper than the disc brake and not requiring any servo actuation, is quite efficient enough to satisfy all reasonable requirements.

Most manufacturers are now equipping their cars with such "safety devices" as padded sun visors and instrument boards, dished steering wheels, and brackets for safety belts, but the practical value of such measures is regarded as rather doubtful.

There were some indications at the show of such engineering changes as will permit longer intervals between radiator flushes, greasing jobs and oil changes, while others, like the more general use of die-cast aluminium cylinder blocks, a.c. generators, with diode rectifiers, simplified electric circuits and silencers of non-corrosive material are still in their infancy.

(*To be continued*)

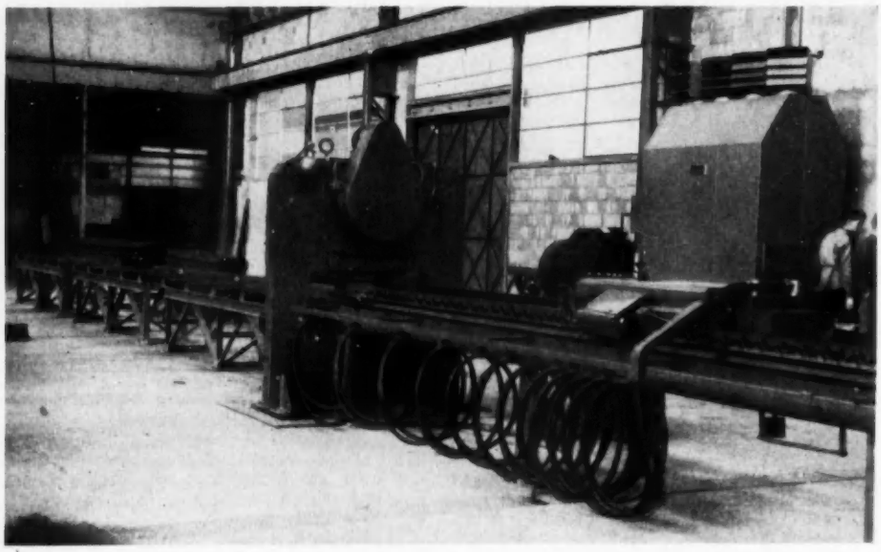
Automatic Punching Machine for Structural Steel

A MACHINE for punching holes automatically to close limits without need for marking out in structural steel sections, has been developed by Sirugue et Cie., 113-115, Avenue Michelet, Saint-Ouen (Seine), France (representatives, J. V. Morand, Ltd., Clyburn House, Brook Mews North, Craven Road, London, W.2). With this machine holes up to 1 $\frac{3}{16}$in diameter in $\frac{1}{2}$in thick material can be punched in angles, flat bars, channels or joists, in 46ft lengths and weighing up to 1 ton. Either single or twin punches (at adjustable transverse centres) can be used to punch one or two holes in a section, or one hole in each of two sections at each indexing movement along the length. The

CONTINENTAL AFFAIRS *(Continued)*

machine, illustrated on this page, comprises a "bridge" type punching machine with a roller feed bench on one side and a conveyor bench on the other side. A saddle on the conveyor bench draws the work through the press and automatically halts at predetermined intervals whilst the holes are punched.

The punching machine, of heavy welded plate design, has a work aperture 19in high and 36in wide in the frame and is driven by a 3 h.p. motor at thirty strokes a minute. Its twin rams are driven by eccentrics through independent clutches and have a stroke of 1⅛in. The foot of each ram carries a slotted punch holder along which the punch assemblies can be adjusted in accordance with the required transverse hole centres. Slotted baseplates in the frame aperture used for mounting of the die bolsters allow their ready alignment with the punches.



Machine for automatically positioning and punching holes in structural steel sections

The benches on either side of the machine are set at a fixed height and to provide means of adjustment to comply with different work heights the punching machine itself is mounted on an elevating platform. This platform, which gives the machine a height adjustment range of 1ft, is operated through worm gearing driven by a 1·5 h.p. motor.

The conveyor bench is built up of three similar 16ft 5in long sections locked together end to end. Each section is built up from two rolled steel plate longitudinal side members rigidly braced together. Slots along the inside of the side members carry high-tensile steel racks, and brackets between the members support the rollers along which the work is supported. A saddle or carriage which draws the work through the punching machine is mounted on rollers running along tracks machined on the top faces of the bench side members and its alignment is maintained by side rollers on the inside of the tracks. A two-speed motor in this saddle drives a worm shaft having pinions at each end meshing with the longitudinal racks. The motor is fitted with a brake and this in conjunction with a locking device on the worm shaft ensures instantaneous stopping of the saddle. When pulling work through the punching machine the saddle is moved at a speed of 23ft per minute by the two-speed motor and when the saddle is being returned to its starting position this speed is doubled. The saddle front is fitted with two sets of quick operating clamps for gripping the work and pulling it through the machine.

The positions at which holes are punched are determined by the setting of "stop-blocks" along a graduated scale set on an inclined face along the side of the bench. These stop blocks incorporate permanent magnets which hold them firmly on the scale and at the same time permit their easy adjustment. A photo-electric unit is fitted on the saddle and registers with the stop blocks as the saddle moves along the track pulling the work through the punching machine. When a stop block appears in front of the photo-electric unit it obscures the light beam and this produces a pulse which is amplified and relayed to the main control panel. As a result of this signal, power to the saddle motor is cut off and its brake applied, the saddle is locked on the track by an electro-magnet and the clutch of the punching machine engaged. At the completion of the punching cycle a trip on the clutch lever is operated and the control gear acts to unlock the saddle and start its motor to begin movement to the next setting. Where holes are spaced widely apart the travelling speed of the saddle can be increased to 46ft per minute to reduce the time involved in positioning; this is achieved by placing a white strip up to 2ft 6in long on the setting scale. When the photo-electric beam registers on this white strip the higher speed range is engaged.

The photo-electric system actually comprises two groups each with two photo-electric cells in parallel and exposed to two sources of light. This application is provided for work where holes have to be staggered and where the distance of the centres is less than 1 ⅞in. It is claimed that this machine can punch holes having centre distance tolerances within ±0·020in in successive structural members.

French Diesel-Injection Equipment Factory

On September 21, the official opening took place of a new factory at Blois (Loir-et-Cher) for the manufacture of diesel-injection equipment. Our illustration shows one of the bays of the factory which has a floor area of 8000 square metres and will eventually employ 600 workers, a useful addition of industry in what is still an almost wholly agricultural part of France. The plant is being operated by Roto Diesel S.A., a company owned jointly by C.A.V., Ltd., and the French D.B.A. Group, of which the leading constituent companies are Ducellier (automotive electrical equipment), Bendix (vehicle brakes), and Air Equipment (aircraft fuel systems and electrical equipment). Production will centre on the "DPA" distributor fuel injection pump first introduced by C.A.V. in 1956.

Over 200 machine tools have been installed at the £1·5 million factory of which certain parts are air-conditioned with the temperature held constant to within ±0·5 deg. Cent, a measure essential for holding the very fine machining tolerances which for certain components are from 1 to 3 microns. The aim is to produce 100,000 injection pumps per annum, compared with an annual output of 250,000 from the C.A.V. factory at Rochester.

One of the bays of the Roto diesel factory at Blois

THE AMERICAN SCENE

By Our American Editor

X-Ray and Gamma Ray Calibration at the N.B.S.

To assist science and industry in the measurement of X-rays and gamma-rays, the National Bureau of Standards calibrates instruments for use as laboratory standards. These instruments are calibrated with X-ray beams measured with a free-air ionisation chamber, and with gamma-ray beams obtained from radio-active isotope sources and measured with an air-filled, graphite cavity ionisation chamber. Correction factors thus obtained may be used to correct the instrument scale readings.

THE rapid growth of atomic and nuclear technology has increased the need for accurate measurements of radiation. To assist users of instruments in making accurate measurements, the National Bureau of Standards, of Washington, D.C., calibrates instruments for use as laboratory standards. This is done at present using a wide range of dose rates of X-rays produced at tube potentials from 20kV to 250kV and gamma-rays obtained from cobalt 60. A caesium 137 source will also be available soon for instrument calibrations.

X- and gamma-rays are being used in an ever-increasing number and wide range of industrial, scientific, and medical applications. Such uses include the examination of large castings, the treatment of cancer, and studies of the effects of radiation on various materials. In order that experiments carried out in one laboratory may be compared with those in another laboratory, there must be a common basis for measurement. Through its calibration services, the Bureau provides laboratory standards which contribute to the accuracy of such comparisons.

Instrument Requirements

The instruments received for calibration are limited to those suitable for use as standards. At the present time, these instruments all use the ionisation produced in a small air-filled cavity chamber of the instrument as a measure of the radiation. Two methods are used for measuring this ionisation. In one type of instrument, the cavity chamber is separated during exposure from the rest of the instrument which contains the " readout " system. Before separation, the chamber is charged to a fixed potential as indicated by the readout system. After charging, it is removed from the readout system for exposure to radiation for a timed period, and then reconnected for reading. The loss in charge due to ionisation is indicated by a change in the readout. An example of this type of instrument is shown in Fig. 1, with a chamber used for measuring gamma rays.

The other type of instrument employed as a laboratory standard is a three-electrode ionisation chamber used in connection with a highly precise system for measuring very small ionisation currents of the order of 10^{-12} A. This system ordinarily consists of an air capacitor which collects the charge from the ionisation current during an accurately timed period, a vibrating-reed electrometer used as a null detector, and a precision potentiometer to measure the potential developed on the air capacitor. The accuracy of this type of ionisation chamber and measurement system is somewhat greater than that of the portable radiation meter, but the apparatus is more complex and costly. A chamber system of this type is used for the inter-comparison of standards.

X-Ray Source

The X-rays used at the Bureau for calibration work are generated by applying constant potentials up to 250kV to oil-cooled industrial X-ray tubes with tungsten targets. Fig. 2 shows such a tube suitable for operation at 250kV. The power input to the equipment is stabilised and automatic controls assist in holding the X-ray output steady within a few tenths of one per cent. The X-ray tube used with the low-energy standard below 100kV has a beryllium window to permit the transmission of the longer wavelengths. Additional shielding material is placed around the tubes to reduce the stray radiation reaching the calibration instruments. In the case of the 250kV tube, this additional shielding amounts to ¼in of lead and ½in of steel. A set of interchangeable lead portal diaphragms, shown in Fig. 3, permits limiting the X-ray beam to the diameter actually required. A shutter, consisting of a hole drilled in a 1in thick lead block, is moved back and forth in front of the tube portal by means of a pair of solenoids. The exposure time is controlled by the opening and closing of this shutter.

Radiation from the X-ray tube is composed of a wide range of wavelengths and is passed through metal sheet filters, to reduce the spectral width. The longer wavelengths are differentially attenuated more than the shorter wavelengths. These

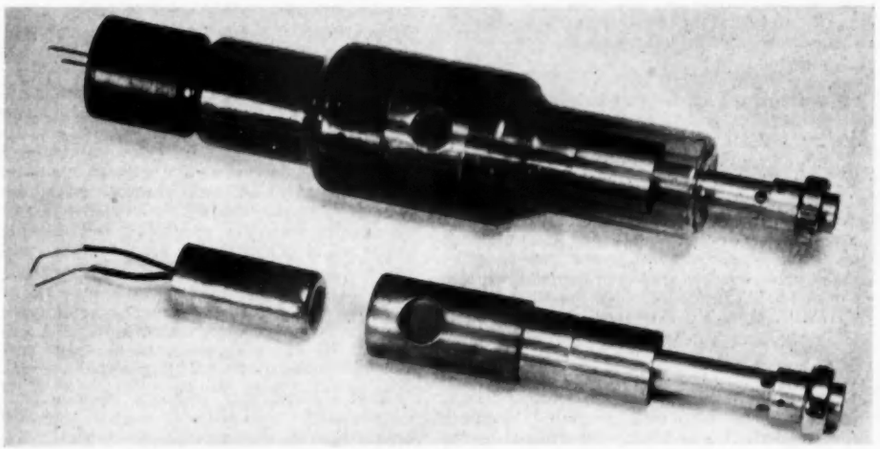


Fig. 2—250kV X-ray tube used for instrument calibration, with filament, tungsten target, beryllium disc and an exit window in the glass

Fig. 1—Ionisation chamber being attached to its electrometer for a reading after an exposure to gamma rays

THE AMERICAN SCENE *(continued)*

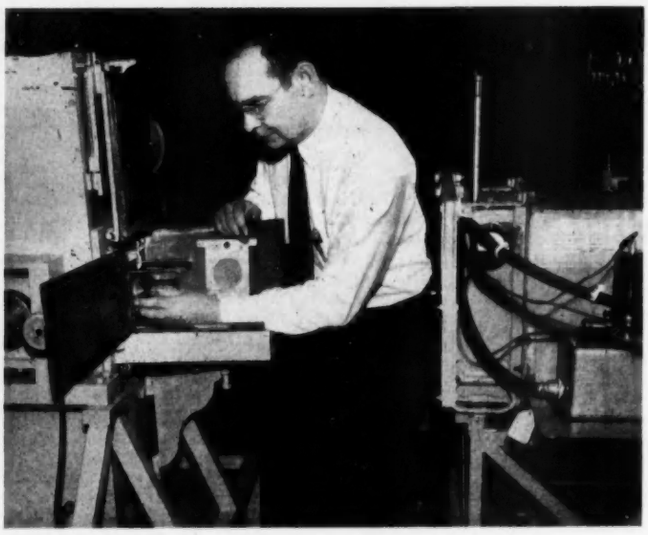


Fig. 3—Lead portal diaphragm being applied to X-ray beam, with free-air ionisation chamber at right, within lead shielding

Fig. 4—Standard free-air ionisation chamber in use at the National Bureau of Standards

filters of copper and aluminium, or special combinations of lead, tin, copper and aluminium, are chosen for the particular kilovoltage and desired spectral range. The number of such combinations used for calibrations is limited, in order to ensure the use of the same conditions when subsequent calibrations are made.

Standard Free-Air Chamber

X-ray beams used for instrument calibrations are measured with a standard free-air ionisation chamber. Such a chamber is designed to meet the requirements inherent in the definition of the roentgen, the unit of X-ray exposure dose. The Bureau's chamber, shown in Fig. 4, is made up of parallel vertical plates of aluminium, spaced 20 centimetres apart, and enclosed in a lead-lined box to keep out stray radiation. A tungsten diaphragm with an aperture diameter of 1cm is placed at the front end of the box to define the narrow X-ray beam which passes along the axis of the chamber between the plates. A potential of 5kV, applied between the plates, separates the charged particles produced in the air and sweeps the ions of one polarity from a defined length of the air to the collector plate. To ensure that this length is accurately determined by the collector plate, the lines of force along which the charges move must be parallel to each other and perpendicular to the face of the collector plate. A system of guard plates adjacent to the collector and a series of guard wires around the plate system establish the required uniformity of field.

As the roentgen is defined in terms of ionisation for a given mass of air, the density of the air in the defined air volume must be corrected to the standard conditions of atmospheric pressure and temperature—760mm of mercury and 0 deg. Cent. Corrections are also made for other deviations from the defined conditions, such as attenuation of the X-rays by the air between the chamber diaphragm and collector plate ; loss of ions through recombination ; contribution from the Compton-process scattered photons ; moisture content of the air ; and a number of similar small corrections, the magnitudes of which have been determined for the various conditions of use.

The ionisation current is measured by means of a circuit connected to the collector-plate, consisting essentially of a standard capacitor, a vibrating-reed electrometer, and a potentiometer. The ionisation current flowing on to the condenser plates causes a change in potential which is registered by the electrometer. The magnitude of this potential change is read as the potentiometer voltage required to bring the electrometer needle back to its null position on the meter scale. The charge accumulated on the air capacitor during the timed exposure is determined from the capacitance and the change in potential.

X-Ray Calibration Procedure

Instruments submitted as laboratory standards are calibrated with X-ray beams measured by the Bureau's standard free-air chamber, using a substitution procedure. The X-ray beam is first measured with the free-air chamber, the point of measurement being the defining aperture of the diaphragm. The chamber being calibrated is then placed at this same point in the X-ray beam, after moving the free-air chamber aside, and measurements are made with it. Finally, the free-air chamber is again positioned and measurements made of the X-ray beam, to determine whether the beam intensity has remained constant. Corrections are then made to the measurements, to convert them to standard conditions of atmospheric temperature and pressure.

Gamma-Ray Calibration

Several gamma-ray sources, providing collimated beams covering a wide range of intensities, are used for the calibration of instruments. Two of the more frequently used sources consist of capsules containing cobalt 60, positioned below floor level within heavy lead shields. Above the capsules are cylindrical lead shutters which are rotated to permit a narrow gamma-ray beam to pass vertically upward through the shutter opening. Fig. 5 shows an ionisation chamber positioned ready for exposure above one of the shutters. A movable instrument support aligned with one or other of the beams can be used to position the instrument at the desired distance from the source. The vertical gamma-ray beams are calibrated in terms of roentgens per hour by measuring the beam at many positions above the source, using a graphite, air-filled cavity ionisation chamber. Proper consideration of the various parameters of such a chamber permit its use for measurements in terms of roentgens. One of the important factors is the stopping power for ionising particles of the wall material of the cavity chamber compared to that of the filling gas. This ratio, dependent slightly on the energy of the radiation, is derived from various experimental investigations. The values of relative stopping power chosen for use with the Bureau's cavity chamber for carbon to air are 1·003 for cobalt 60 and 1·007 for caesium 137 gamma rays.

The data from measurements at various source distances in the beams have been used to develop an equation which permits computing the dose rate at intermediate points. The values must also be corrected for the decay of the radioactive material. Although this correction is valid over short periods of time, periodic checks are made with the graphite chamber to verify this. The chambers of radiation meters submitted for calibration are charged to zero scale reading, positioned at a preselected height above one of the sources, and exposed to the beam for a time period that will produce a reading near mid-scale.

Fig. 5—Ionisation chamber for gamma-ray calibration ready for exposure from cobalt-60 source

As with the X-ray calibration, a correction factor is computed that will convert the instrument reading to the known value of the source.

Two additional vertical-beam gamma-ray calibration ranges have recently been added to the facilities of the laboratory. These consist of tungsten and lead-shielded source-housings, supported about 6ft above floor level. Each provides narrow gamma-ray beams directed downward toward a 6ft deep lead-lined pit which acts as a beam trap to reduce scattered radiation. One of these units has about 1000 curies of cobalt 60 and the other, 2000 curies of caesium 137. The higher dose rates of these devices are particularly useful in the calibration of higher-range instruments.

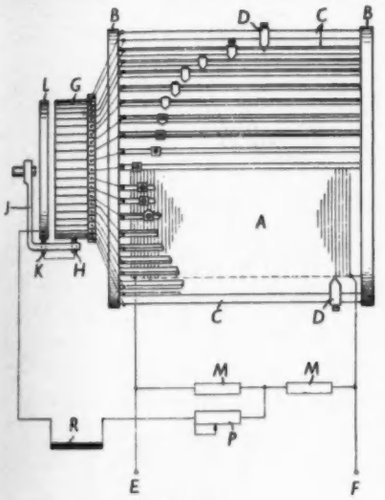
BRITISH PATENT SPECIFICATIONS

The data printed are those o application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

ELECTRICAL ENGINEERING

875,593. June 11, 1958.—DEVICE FOR OBTAINING PERIODICALLY VARIABLE CURRENTS, Licentia Patent-Verwaltungs-G.m.b.H., 1 Theodor-Stern-Kai, Frankfurt-am-Main, Germany.

This invention relates to a device for producing periodically variable currents, varying in magnitude and if desired also in direction. Such currents are required, for instance, for the control of butt-welding machines in accordance with a set programme, or for the production of periodically-varying magnetic fields or acoustic oscillations for mine sweeping installations. As shown, a resistance wire is wound in the form of a coil *A* on a cylindrical carrier provided with two discs *B*. The diameter of the discs is larger than that of the cylindrical carrier so that the discs project flange-like from the carrier and serve for the support of conductive guide rails *C* supporting sliding contacts *D* which contact the resistance wire and can be fixed in a set position by means of a screw. Thus, each guide rail with its sliding contact forms together with the resistance wire a variable resistor. The ends of the resistance wire are connected to terminals *E* and *F* to which a direct-current source can be connected. Each guide rail *C* is connected to a segment of a commutator-like contact device *G*. A brush *H*, which collects the current from the segments of the contact device, is fixed to an arm *J* which is rotatably mounted about a shaft coaxial with



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the contact device. In order to derive the current from the revolving brush, the arm has another sliding contact *K* which coacts with a stationary slipring *L* which is coaxial with the contact device. An output wire is connected to the stationary slipring. Two fixed series-connected resistors *M* are connected in parallel to the resistance wire coil so that a resistor bridge circuit is formed. Two arms are formed by the resistors *M*, and the two other arms by the portions of the resistance wire coil determined by the axial position of the sliding contact *D* of the variable resistor which happens to be connected through a segment of the contact device and through the brushes to the stationary slipring *L*. Slipring *L* is connected to a point between the two fixed resistors *M* so that the connection from this point via the slipring brushes, a segment *G* and a rail *C* to a sliding contact *D* forms the diagonal of the bridge. It includes a coil *R*, for instance the field winding of an electric machine, and a resistor *P* for adjustment of the amplitude of current through the diagonal. In order to obtain the desired form of control current, the sliding contacts are shifted along the rails into the position corresponding to the desired resistance values, and they are then clamped in their position. When the arm *J* is then rotated, the brushes connect the individual variable resistors in circuit in succession; the instantaneous current in the bridge diagonal will then depend on the adjustment of the connected variable resistor. If the sliding contact of a variable resistor is exactly in the middle of the resistance coil, the current will be zero because the bridge is balanced. Maximum current will flow when the sliding contact is in one of the two end positions. In the one end position, the current will flow in the one direction, and in the other end position, the current will flow in the opposite direction. The frequency of the current variations can be adjusted by adjusting the rotary speed of the brushes around the segments of the contact device.—*August* 23, 1961.

875,958. January 30, 1957.—CONTROL SYSTEMS FOR ELECTRIC MOTORS, Contactor Switchgear, Ltd., Moorfield Road, Upper Villiers Street, Wolverhampton, Staffordshire. (*Inventor: Richard Alfred West.*)

This invention relates to control systems for obtaining synchronous running of electric motors used for independent drives, and is particularly applicable in cases where heavy inertia loads requiring to be frequently started and stopped are provided with two independent drives and where there is a tendency for the mechanical conditions to cause a loss of the required synchronism between the drives. The invention is thus suitable for travelling structures such as travelling outdoor gantry cranes or overhead cranes which run on two rails and have traction motors for driving independently the driving wheels on each rail. With such structures there is often a relatively wide space between the two rails and the structure is liable to become out of alignment on the rails owing to unequal speeds of the traction motors caused by unequal loading or unequal friction resistance, and to prevent such misalignment it is necessary to ensure that the motors always operate in synchromism, at the same speeds. The specification illustrates an arrangement of two slipring motors with their rotors coupled to form a selsyn system. The two rotors are provided with a common resistive load under the control of speed-responsive relays fed through a rectifier from the rotors. Acceleration of the motors may be controlled by timing relays. When the motors have reached a predetermined speed, one of the speed-responsive relays operates to remove driving or accelerating torque from the motors, although the synchronous selsyn connection is maintained. With a heavy inertia load, such as an overhead crane, most of the effort of the driving motors is required in accelerating or decelerating, and once the load is moving it will continue at a steady speed with very little effort. Removal of the driving torque will therefore normally ensure that the load does not increase further in speed, but will continue to coast. However, should the speed tend to increase beyond the selected value, a further speed-responsive relay may cause reversal of the stator fields to provide powerful counter-current braking. As an alternative, this braking may be applied manually, the operation of the second relay being arranged merely to actuate a warning device. The relays should be double-acting, so that after operation in one sense as the speed of the motors reaches a critical value, subsequent reduction in speed will cause operation in the opposite sense so that the original conditions are restored. The synchronous selsyn correction between the motors is maintained until standstill is reached.—*August* 23, 1961.

ELECTRONICS

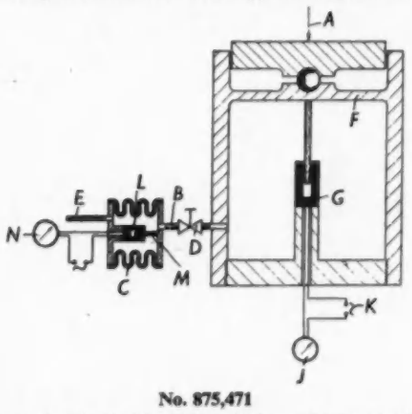
875,918. January 14, 1957.—VEHICLE IDENTIFICATION SYSTEM, The Plessey Company, Ltd., 56, Vicarage Lane, Ilford, Essex. (*Inventors: Harold George Stubbs, Francis Alfred Judd, Bernard Vincent Wickenden and John Henry Nicoll.*)

This invention relates to the identification of, or reading of information about, bodies moving at various speeds along a predetermined path in the vicinity of a given observation point. It is more particularly intended for the identification of vehicles moving past an observation point, its primary intended application being for the identification of railway vehicles. According to the invention the information is obtained by means of a microwave transmitter arranged at a point which is passed by the vehicle and constructed to emit a stationary beam of a frequency lying in the centimetre or millmetre waveband. Each vehicle from which information is to be obtained is provided with a coded linear array, extending longitudinally, of alternate reflecting and non-reflecting surfaces. Motion of the object about which information is sought causes areas of non-reflecting and reflecting surfaces on the exterior of the body to pass successively across the beam according to the codes, while a stationary receiver is arranged to respond when a reflecting surface passes the beam but not to respond when a non-reflecting surface passes. The term "non-reflecting surfaces" is intended to cover absence of material, i.e. a hole, materials of low reflecting power, materials of large reflecting power so placed as to reflect away from the receiving point, and materials of appropriate thickness in the direction of the beam, and of such constitution as to act as absorbers of the microwave energy. While some useful results could be obtained by merely distinguishing individual vehicles by the number of reflecting surfaces on each vehicle, the areas of non-reflecting and reflecting material are preferably arranged in each vehicle in a pre-determined distinctive pattern, utilising for example reflecting surfaces of different lengths in the longitudinal direction of the vehicle to constitute distinctive signal elements. Since in this case the duration of each pulse received depends not only on the length of the reflecting surface, but also on the speed, means may be provided, according to a feature of the invention, which render evaluation of the signals received substantially independent of the speed of the vehicle. This may be achieved by arranging along the vehicle a second array of reflecting and non-reflecting surfaces, extending parallel to the first array, and by providing a second receiver into which the beam is transmitted by the reflecting surfaces of the second but not of the first array, while the first receiver is arranged to receive only the beam when reflected by the surfaces of the first array. The two receivers are interconnected in such manner that output signals are produced by co-operation of the two. For example, the second array and receiver may constitute a timing device or variable timebase, the array consisting of alternate reflecting and non-reflecting surfaces of standard length, whereby the second receiver will produce timing pulses of a length which varies with the speed of the vehicle proportionally as the length of the coded pulses of the first array is affected by the vehicle speed. The length value of each pulse received by the first receiver can then be determined by a count of the pulses of the second receiver arriving during its reception.—*August* 23, 1961.

DYNAMOMETERS

875,471. July 25, 1958.—DEVICE FOR MEASURING FORCES, Maschinenfabrik Augsburg-Nurnberg, A.G., Nuremberg, Germany.

Thrust dynamometers comprising a chamber in the form of a hollow cylindrical body in which the elastic deformation of the chamber is used as a measure for determining the magnitude of the forces have the disadvantage of having a very restricted measuring range. The object of the invention is the provision of a measuring device comprising an elastically deformable chamber which will be capable of operating within a number of measuring ranges. Referring to the drawing the measured force *A* is applied to the cover of the casing by a thrustor and a ball. The casing is completely sealed and filled with a liquid of low compressibility, such as mercury or concentrated sulphuric acid. The chamber can communicate through as short as possible a pipe *B* with deformable corrugated tube *C* both ends of which are closed, apart from the pipe and a pipe line *E*. The casing represents the measuring chamber, whereas the corrugated tube embodies the supplementary chamber



No. 875,471

according to the invention, which can be connected with or disconnected from the measuring chamber by the stop valve *D*. The deformation of the measuring chamber is represented by a deflection of the membrane *F* of its casing. The deflection of the membrane is indicated by an induction sensing device. The coil *G* of the sensing device is secured to the floor of the measuring chamber and the plunger to the cover. The position of the plunger in relation to the coil, as determined by the deflection of the membrane, controls the current passing through the coil. The current flowing through the coil is used to measure the deformation of the measuring chamber which in turn measures the magnitude of the applied force, the

current being indicated by the instrument *J* connected with the coil. The current flowing through the coil is generated in a source of alternating potential *K* in circuit with the coil and indicating instrument. A second induction-type sensing device may be associated with the supplementary chamber *C*. The elements for measuring the deformation, a coil *L* and a plunger *M*, are similarly located in the supplementary chamber, the coil being affixed to one of the cover plates and the core to the plate at the opposite end of the tube. The alternating current passing through the coil which in the same way depends upon the degree of deformation of the tube is indicated by an instrument *N*. This supplementary device will naturally operate only when the intercommunicating stop valve is open. The advantage offered by the arrangement is that when the supplementary chamber is used the deflections will be large as they are magnified in the ratio of the cross sections of measuring chamber and supplementary chamber. These large deflections may permit an additional extension of the total measuring range. If desired several measuring chambers may be connected with one common supplementary chamber. The connection of a second measuring chamber with the supplementary chamber is indicated by pipe line *E* in the drawing.—*August* 23, 1961.

BRIDGES

876,167. April 23, 1959.—BRIDGE SUPPORTING ASSEMBLIES, Societa Applicazioni Gomma Antivibranti S.A.G.A. Societa per Azioni, 88, via Ripamonti, Milan, Italy.

It is an object of this invention to provide a resilient supporting assembly which is cheap and simple to manufacture, and which will allow for thermal expansions of the members. There is provided a resilient supporting assembly which includes a stack of alternating rubber and metal plates. Each plate is formed with a pair of crossing ribs on one face and a pair of crossing grooves in its opposite face. The ribs on rubber and metal plates engage in respective grooves and provide the only connecting means between the plates to prevent relative sliding movements.—*August* 30, 1961.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Sept. 29.—COVENTRY AND DISTRICT BRANCH: Conservative Rooms, 16, Queen's Road, Coventry, "Load Tanks for Testing Large Alternators," G. Dawson, 8 p.m. ★ STOKE AND CREWE BRANCH: Royal Hotel, Crewe, "Static Switching Control," B. A. W. Midgley, 7.30 p.m.

Mon., Oct. 2.—BOLTON BRANCH: Railway Hotel, Trinity Street, Bolton, "Electrical Aspects of Lifts," W. Scholfield, 7.45 p.m. ★ LEEDS BRANCH: Great Northern Hotel, Leeds, "Fire and Burglar Alarms," G. E. Martin, 7.30 p.m. ★ SHEFFIELD BRANCH: Royal Victoria Hotel, Sheffield, "Photo-Electric Cells as Applied to the Electrical Industry," R. Brown, 7.30 p.m. ★ SOUTH ESSEX BRANCH: Angel Hotel, Ilford Broadway, Ilford, "Public Space Lighting," W. S. Whitaker, 8.15 p.m. ★ SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Protective Equipment for Industrial Plant," W. L. Stern, 7.30 p.m.

Tues., Oct. 3.—BRISTOL AND WEST OF ENGLAND GRADUATE BRANCH: Grand Hotel, Bristol, Chairman's Address, "Design and Estimating of Electrical Installations," T. M. Dickason, 8 p.m. ★ SOUTH EAST LONDON BRANCH: Eltham Green School, Queenscroft Road, Eltham, London, S.E.9, "Heat Pumps," Miss M. V. Griffith, 7.45 p.m. ★ WEST LONDON BRANCH: The White Hart, 49, King's Road, Chelsea, London, S.W.3, "Recent Developments in the Electricity Supply Industry," M. R. G. Paice, 7.45 p.m. ★ READING AND DISTRICTS BRANCH: Caversham Social Club, Caversham, Reading, "Electrical Traction," T. Bingham, 7.30 p.m.

Wed., Oct. 4.—NORTH LONDON BRANCH: Wood Green Civic Centre, Wood Green, London, N.22, "Electrical Aids to Labour-Saving in the Home," Miss Lois Stevens, 8 p.m. ★ MANCHESTER BRANCH: N.W. Electricity Board Service Centre Theatre, Town Hall Extension, St. Peter's Square, Manchester, 2, "Safety in the Utilisation of Electricity," S. J. Emerson, 7.30 p.m. ★ PRESTON BRANCH: Farmer's Arms Hotel, Market Street, Preston, "Motor Vehicle Electrical Equipment," 7.30 p.m.

Thurs., Oct. 5.—BRIGHTON, HOVE AND DISTRICT BRANCH: The Cricketers Hotel, Black Lion Street, Brighton, 1, "The Police," 7.30 p.m.

Fri., Oct. 6.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Applications and Failures of Ball and Roller Bearings," R. W. Jones, 7.30 p.m.

BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION

Thurs. and Fri., Oct. 5 *and* 6.—Connaught Rooms, London, W.C.2, Two-day Golden Jubilee Export Conference.

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., Oct. 3.—ELECTRO-ACOUSTICS GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Methods Used for the Study of Vibration in Aero Engines," D. A. Drew, 6 p.m. ★ SOUTH WALES SECTION: Welsh College of Advanced Technology, Cardiff, "The S.E.C.A.M. Colour Television System," G. B. Townsend, 6.30 p.m.

Thurs., Oct. 5.—NORTH WESTERN SECTION: Reynolds Hall, College of Technology, Manchester, "Basic Principles of Digital Computers," 7 p.m.

Fri., Oct. 6.—SOUTH MIDLANDS SECTION: North Gloucestershire Technical College, Cheltenham, "Colour Television," P. S. Carnt, 7 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Tues., Oct. 3.—WESTERN REGION: Park Hotel, Cardiff, Discussion on "The Factories Acts in Relation to Boilers and Pressure Vessels," opened by H. Entwistle, 10 a.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Oct. 2.—BATH AND BRISTOL CENTRE: Gardiner, Sons and Co., Ltd., Bristol, Chairman's Induction and Address, 6 p.m.

Tues., Oct. 3.—EDINBURGH CENTRE: Y.M.C.A., 14, South St. Andrew Street, Edinburgh, "The New I.E.S. Code," R. Croft, 6.15 p.m. ★ SWANSEA GROUP: Demonstration Theatre, South Wales Electricity Board, The Kingsway, Swansea, Chairman's Address, 6 p.m.

Thurs., Oct. 5.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "The New I.E.S. Code," R. Croft, 6.30 p.m.

Mon., Oct. 9.—LIVERPOOL CENTRE: Industrial Development Centre, Paradise Street, Liverpool, Chairman's Address, N. Blackman, 6 p.m. ★ SHEFFIELD CENTRE: Grand Hotel, Sheffield, Chairman's Address, B. Ruston, 6.30 p.m.

Tues., Oct. 10.—STOKE-ON-TRENT GROUP: North Stafford Hotel, Stoke-on-Trent, "Stage Lighting," B. Legge, 6 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Oct. 11.—SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Use of Oxygen in Cupolas and Other Developments," C. H. King, and F. B. Lawrence, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Oct. 2.—MERSEYSIDE AND NORTH WESTERN SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "The Chemical Cleaning of Ships' Machinery," H. R. Hamburg and P. F. Dilnot, 6 p.m. ★ STUDENT MEETING: Memorial Building, 76, Mark Lane, London, E.C.3, Technical Film Show and Introductory Talk, S. G. Christensen, 6.30 p.m.

Tues., Oct. 3.—Memorial Building, 76, Mark Lane, London, E.C.3, Presidential Address, "The Marine Engineer and the Common Life," C. C. Pounder, 5.30 p.m.

Thurs., Oct. 5.—Junior Lecture.—Poplar Technical College, Poplar High Street, London, E.14, "Boiler Water Treatment," C. J. Haslar, 6.30 p.m. ★ KINGSTON-UPON-HULL AND HUMBER AREA SECTION: Royal Station Hotel, Kingston-upon-Hull, "Marine Diesel Engine Bearings: Materials and Design," P. T. Holligan and R. W. Joy, 7.30 p.m.

Mon., Oct. 9.—WEST OF ENGLAND SECTION: Small Engineering Lecture Theatre, The University, University Walk, Bristol, 8, "Water Treatment for High Pressure Marine Boilers," T. V. Arden and F. C. Blight, 7.30 p.m.

Tues., Oct. 10.—DEVON AND CORNWALL SECTION: Demonstration Theatre, S.W. Gas Board, Radiant House, Derry's Cross, Plymouth, "Marine Refrigeration Machinery" Lt. Cdr. M. B. F. Ranken, 7.15 p.m. ★ LONDON SECTION: Memorial Building, 76, Mark Lane, London, E.C.3, "A Critical Survey of Marine Water Treatment Methods," I. Raleigh, 5.30 p.m.

INSTITUTE OF METALS

Tues., Oct. 3.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, "High Temperature Alloys," W. Betteridge, 7.15 p.m.

Thurs., Oct. 5.—LEEDS METALLURGICAL SOCIETY: University Staff House, University Road, Leeds, "The Strength of Alloys," R. W. K. Honeycombe, 6.30 p.m. ★ LONDON LOCAL SECTION: 17, Belgrave Square, London, S.W.1, "Plutonium," W. B. H. Lord, 6.30 p.m.

Mon., Oct. 9.—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, C.2, "Physical Methods of Analysis for Major Alloying Constituents," K. M. Bills, 6.30 p.m. ★ TYNE WEAR METALLURGICAL ASSOCIATION: Metallurgy Department, King's College, Haymarket, Newcastle upon Tyne, "Modern Developments in Steelmaking," J. Pears, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 4.—Lecture Theatre, 61, New Cavendish Street, London, W.1, "The Packaging of Lubricants," H. G. Priest, 5.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

To-day, Sept., 29.—ELECTRONICS GROUP: Assembly Room, Town Hall, Leamington Spa, Joint conference on "The Physics of Gas Discharge Devices."

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Oct. 2.—MANCHESTER AND DISTRICT CENTRE: Engineers Club, Albert Square, Manchester, "Glass Fibre Reinforced Plastics," G. O. Gurney, 7.30 p.m. ★ SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "The Roadrailer," J. A. Simms, 7.30 p.m.

Tues., Oct. 3.—EASTERN CENTRE: The Refectory, F. Perkins, Ltd., Peterborough, "Fuel Developments," L. P. F. Drake, 7.30 p.m.

Wed., Oct. 4.—EAST MIDLANDS CENTRE: Empire Hotel, Leicester, "Modern Vehicles for the Motorway," A. H. Carter, 7.30 p.m.

INSTITUTE OF WORK STUDY

To-day, Sept. 29 *to Sun., Oct.* 1.—College of Aeronautics, Cranfield, Annual Conference, "The Scope for Investigation into Office and Sales Procedure."

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 3.—Great George Street, Westminster, London, S.W.1, "Three Prestressed Concrete Railway Bridges," F. Turton, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Oct. 3.—LONDON GRADUATE AND STUDENT SECTION—CHATHAM DISTRICT: Medway College of Technology, Maidstone Road, Chatham, Kent, Chairman's Address, "Experimental Techniques Developed for Determining the Performance of Fuel Elements in Nuclear Reactors," C. F. Price, 7 p.m.

Thurs., Oct. 5.—ORDINARY MEETING: Savoy Place, London, W.C.2, Inaugural Presidential Address, G. S. C. Lucas, 5.30 p.m.

Fri., Oct. 6.—MEDICAL ELECTRONICS DISCUSSION GROUP: Savoy Place, London, W.C.2, Discussion on "What is pH and its Measurements?," opened by G. Mattock and G. R. Taylor, 6 p.m.

Mon., Oct. 9.—LONDON GRADUATE AND STUDENT SECTION—ARBORFIELD DISTRICT: Unit Cinema, 3 (Tels.) Training Bn., R.E.M.E., Arborfield, Berks., Chairman's Address, "Experimental Techniques Developed for Determining the Performance of Fuel Elements in Nuclear Reactors," C. F. Price, 7 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 3.—39, Elmbank Crescent, Glasgow, Presidential Address, "In Search of Economic Stability and Security," I. M. Stewart, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

To-day, Sept. 29 *to Wed., Oct.* 4.—Olympia, London, S.W.7, International Conference on Heating, Ventilating and Air Conditioning to be held during the Exhibition of Heating, Ventilating and Air Conditioning Equipment.

Tues., Oct. 3.—NORTH EAST COAST BRANCH: Institute of Mining and Mechanical Engineers, Neville Street, Newcastle upon Tyne, "Heating and Ventilating in Modern Offices or Hotel Blocks with Emphasis on High Velocity Single Pipe Systems," C. F. Regenberg, 6.30 p.m.

Wed., Oct. 4.—EAST MIDLANDS BRANCH: College of Art and Crafts, Waverley Street, Nottingham, "Application of Solid Fuel to Central Heating Systems, with Special Reference to the Clean Air Act," 6.30 p.m.

Fri., Oct. 6.—MANCHESTER AND DISTRICT BRANCH: Engineers' Club, Albert Square, Manchester, "A New Approach to the Psychrometric Chart," G. R. Binns, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Mon., Oct. 2.—NORTH EASTERN BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, Chairman's Address, P. Mayne, 6 p.m. ★ LONDON GRADUATES' BRANCH: 1, Birdcage Walk, Westminster, London, S.W.1, The first of a series of eight lectures on "Self Expression in Industry," 7 p.m. ★ NORTH EASTERN GRADUATES' BRANCH: Rutherford College of Technology, Northumberland Road, Newcastle, Chairman's Address, 6.30 p.m.

Tues., Oct. 3.—NORTH EASTERN BRANCH: Cleveland Institute, Corporation Road, Middlesbrough, Repetition of Chairman's Address, P. Mayne, 6.15 p.m. ★ NORTH WESTERN BRANCH: Technical College, Blackburn, "Review of the Objectives and some Development Problems of the Westland Rotodyne," G. S. Hislop, 7.30 p.m. ★ SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Design, Commissioning and Operation of Blyth 'A' Power Station," A. E. Powell and E. Forth, 6 p.m. ★ SCOTTISH GRADUATES' BRANCH: Visit to United Glass, Ltd., Shettleston, Glasgow, 7 p.m.

Wed., Oct. 4.—ORDINARY MEETING WITH THE RAILWAY ENGINEERING GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Some Speculations on the Future of Railway Mechanical Engineering," F. T. Barwell, 6 p.m. ★ YORKSHIRE BRANCH: Afternoon visit to British Oxygen Company, Ltd., Rotherham; The University, St. George's Square, Sheffield, 1, Chairman's Address, H. Townend, 6.30 p.m. ★ EAST MIDLANDS GRADUATES' BRANCH: Technical College, Lincoln, "Vibration Problems in Single Shaft Axial Turbo-Jet Engines," R. C. Moore, 7.15 p.m.

Thurs., Oct. 5.—EAST MIDLANDS BRANCH: The University, Nottingham, Repetition of a Crompton-Lanchester Lecture, "Performance Measurement of the Complete Car," A. Fogg, 7.15 p.m. ★ NORTH WESTERN BRANCH, INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: Engineers' Club, Albert Square, Manchester, "Aesthetics in Engineering," R. H. Litherland, 6.45 p.m. ★ SOUTHERN BRANCH: South Dorset Technical College, Newstead Road, Weymouth, "Construction Problems in the Nuclear Engineering Field," T. G. Williams, 7.30 p.m. ★ SOUTHERN BRANCH: Sarsen's Head Hotel, Ashford, Kent, "Economic Distribution of Steam," J. A. Robins, 7.30 p.m. ★ YORKSHIRE GRADUATES' BRANCH: The University, Engineering Lecture Room 1, Sheffield, "Hydraulic Problems in Rotary Wing Aircraft," A. G. Halstade, 6.45 p.m.

Sat., Oct. 7.—SOUTHERN GRADUATES' SECTION: Visit to the Subscriber Trunk Dialling Telephone Exchange, Aldershot, 10 a.m.

INSTITUTION OF PLANT ENGINEERS

To-day, Sept. 29.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "The Planning, Application and Maintenance of Industrial Lighting," V. J. Neydon, 7.30 p.m.

Tues., Oct. 3.—PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Factory Redeployment for Alternative Production," 7.30 p.m.

Wed., Oct. 4.—EAST MIDLANDS BRANCH: Sherwood Room, County Hotel, Theatre Square, Nottingham, Address by the Chairman, W. K. Martin, 7 p.m. ★ LEICESTER BRANCH: Grand Hotel, Leicester, "Television in Industry," F. L. Valder, 7.30 p.m. ★ SOUTHERN BRANCH: Eastleigh Technical College, Chestnut Avenue, Eastleigh, "The Plant Engineer and Works Study," 7.30 p.m.

Fri., Oct. 6.—BIRMINGHAM BRANCH: Hare and Squirrel Hotel, Cow Lane, Coventry, Ladies' Evening, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Oct. 3.—SCOTLAND REGION: Visit to India Tyre Company, Ltd., Glasgow, 7 p.m.

Wed., Oct. 4.—SOUTH WESTERN REGION: Large Engineering Lecture Theatre, The University, Bristol, "Rocket Propulsion of Aerodynamic and Space Vehicles," E. G. D. Andrews, 7 p.m. ★ NORTH MIDLANDS REGION: Nottingham Reform Club, Victoria Street, Nottingham, "The Application of Spark Machining to Die Making in Different Industries," J. P. Blackshield, 7 p.m.

Mon., Oct. 9.—NORTH WESTERN REGION: Reynolds Hall, Manchester College of Science and Technology, Sackville Street, Manchester, "Spark Machining and Similar Processes," K. Appelbee, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., Oct. 5.—11, Upper Belgrave Street, London, S.W.1, Presidential Address, F. R. Bullen, 6 p.m.

Mon., Oct. 9.—SCOTTISH BRANCH: Institution of Engineers and Shipbuilders, Glasgow, Chairman's Address, K. D. Mathewson, 7 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Fri., Oct. 6.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Illustrated talk, "Lighting Effects of the Palace in Kuwait," R. W. Shaw, 7 p.m.

LIVERPOOL JOINT CHEMISTRY COMMITTEE

To-day, Sept. 29.—Grosvenor Hotel, Morecambe, "Plastics Related to Petroleum," T. S. McRoberts, 8.30 p.m.

Thurs., Oct. 5.—Donnan Laboratories, The University, Vine Street, Liverpool, Chairman's Address, "Modern Food Legislation," G. H. Turner, 7 p.m.

NATIONAL SOCIETY FOR CLEAN AIR

Wed. to Fri., Oct. 4 *to* 6.—The Dome, and the Corn Exchange, Brighton, Annual Conference and Exhibition.

NEWCOMEN SOCIETY

Wed., Oct. 4.—Science Museum, South Kensington, London, S.W.7, Annual General Meeting and "John Rennie (1761-1821)," Cyril T. G. Boucher, 5.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Mon., Oct. 2.—NORTH WESTERN BRANCH: College of Technology, Sackville Street, Manchester, "Hyperbolic Paraboloids," J. D. Bennett, and Charlotte Hume, 6.45 p.m.

Tues., Oct. 3.—NORTH WESTERN BRANCH: Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Hyperbolic Paraboloids," J. D. Bennett and Charlotte Hume, 6.30 p.m.

Advanced Engineering Courses

Advanced Engineering Metrology. NOTTINGHAM AND DISTRICT TECHNICAL COLLEGE, Burton Street, Nottingham. A post-graduate course of twelve lectures will be held on Fridays at 6.45 p.m., commencing Friday, September 29, 1961. The course has been designed for all who are concerned with precise dimensional measurement either in industry or in research; and should also appeal especially to those who have attended previous courses in engineering measurement. The emphasis throughout the course will be on the fundamental principles of metrology, particularly the more recent developments, and it will conclude with a special exhibition of precise measuring equipment. Prior to each lecture, from 6 p.m. onwards, the college Metrology Laboratory will be open for the display of equipment and special measuring techniques. Fee 13s.